WHOI-98-19

Woods Hole Oceanographic Institution

Preliminary Acoustic and Oceanographic Observations from the Winter Primer Experiment

By

Arthur Newhall
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Technical Report

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Approved for public release; distribution unlimited.

Approved for Distribution:

Timothy K. Stanton

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Department of Applied Ocean Physics and Engineering

1.0 Introduction

A joint acoustics and physical oceanography experiment was conducted in the winter of 1997 on the shelfbreak and continental slope south of New England in the Middle Atlantic Bight (figure 1). This experiment, Primer4, provided a seasonal contrast to the previous summer Primer3 experiment and had the same goals and tasks: to study the thermohaline variability and structure of the shelfbreak front and its effects on acoustic propagation. To accomplish the linked oceanographic and acoustic objectives of this experiment, a combination of measurements (fig 2) were made. Seasoar hydrography, shipboard ADCP measurements, Satellite IR sea surface temperature field observations, and AXBT drops were employed to study the larger scale oceanographic fields. To study the finer scale, which includes internal waves, a number of rapid-sampling thermistor strings and current meters, including a moored, upward looking ADCP, were deployed. The acoustics components consisted of three 400 Hz tomography transceivers, a 224 Hz source and two hydrophone arrays. To study the geoacoustic paramters in the bottom a number of SUS charges were also deployed. The field setup was approximately the same for both the summer 1996 and winter 1997 experiments; however the weather conditions and the thermal structure of the mixed layer were radically different. This report is dedicated to the data from the Winter 1997 Primer4 experiment. All data seen here are available online at ftp://acoustics.whoi.edu with permission from the author.

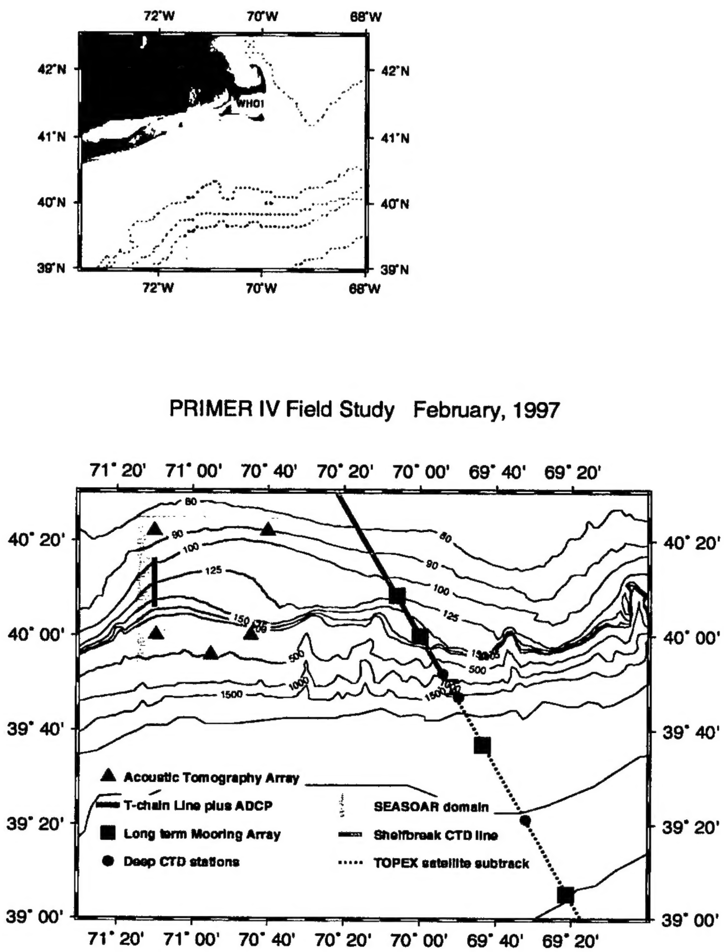


FIGURE 1. Primer4 area of study

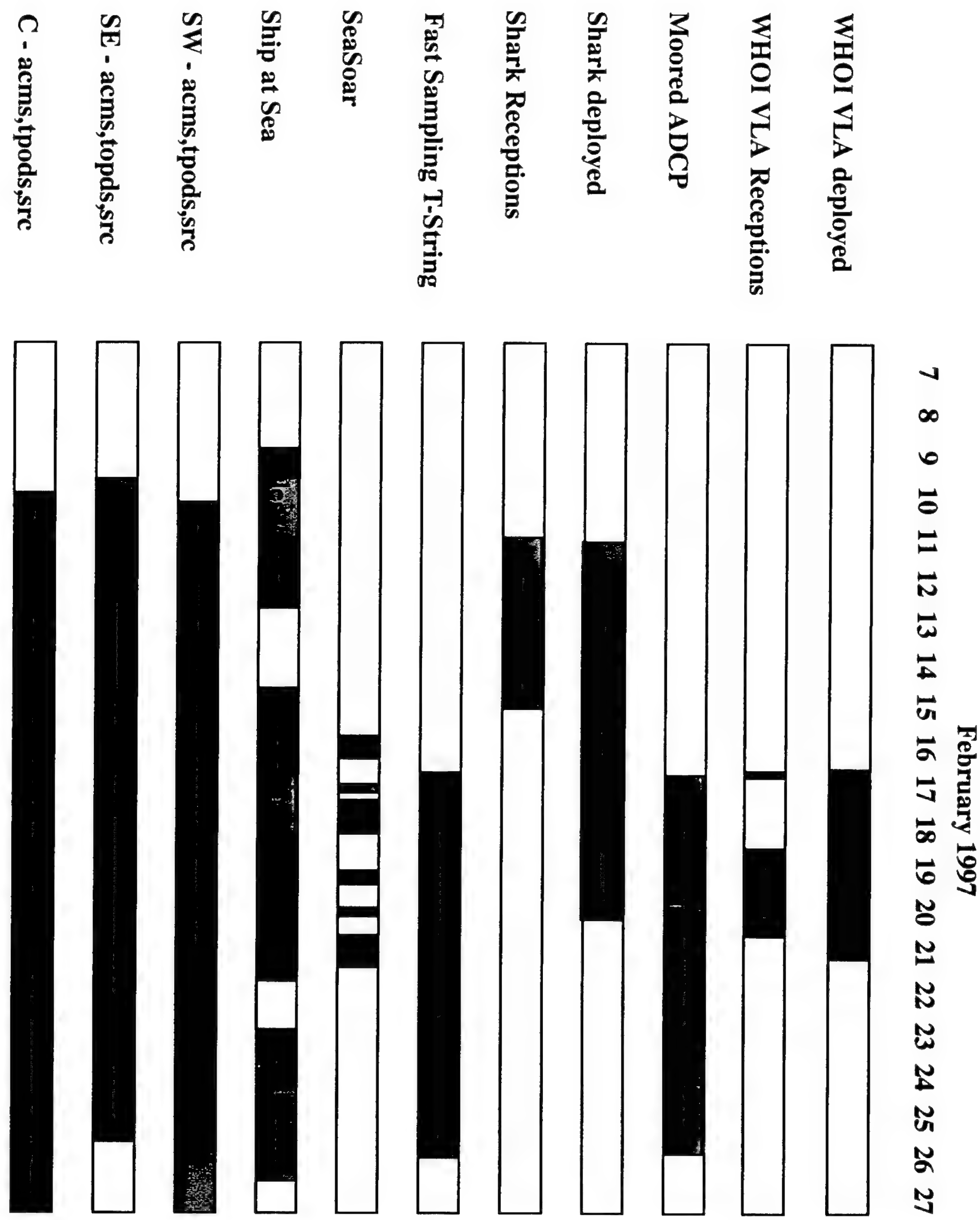


FIGURE 2. Primer4 timeline

2.0 Instrumentation and personnel

Environmental sampling was provided by a moored bottom-mounted ADCP, vertical CTD casts, a field of XBT's, a moored, fast-sampling thermistor chain, satellite sea surface temperature observations, a shipboard ADCP, temperature sensors and current meters attached to the acoustic moorings and large scale SeaSoar hydrography. The acoustic sources used during the experiment were three 400 Hz Webb sources, a 224 Hz Webb source, and air-dropped SUS charges. Two vertical hydrophone systems were used to gather and store acoustic data. One array also provided a horizontal array of hydrophones for a brief time. The western edge of the study area was heavily instrumented while the Eastern edge was relatively sparsely sampled to avoid interfering with submarine lanes near the eastern section (fig 3).

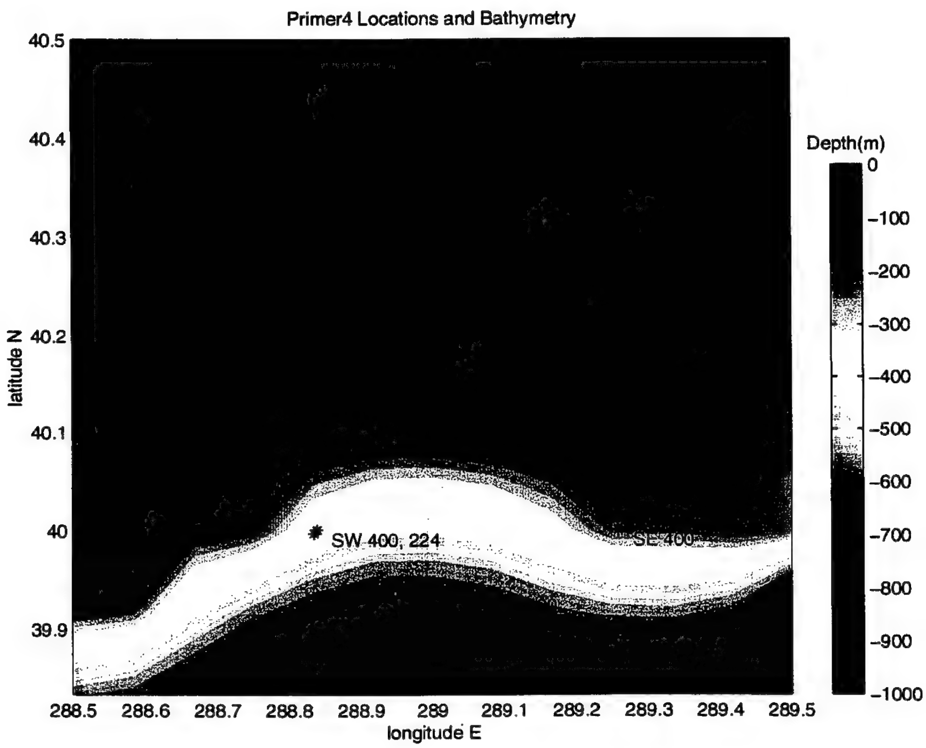


FIGURE 3. Primer4 bathymetry

2.1 Personnel

The ONR sponsored Primer4 experiment was a joint venture that included the Woods Hole Oceanographic Institution (WHOI) AOPE and PO departments, the University of Rhode Island (URI), the Naval Postgraduate School (NPS), Harvard University, and the Lamont-Doherty Earth Observatory (LDEO) at Columbia University (appendix 6.1). The research vessel R/V ENDEAVOR was used for both the summer and winter cruises.

2.2 SeaSoar

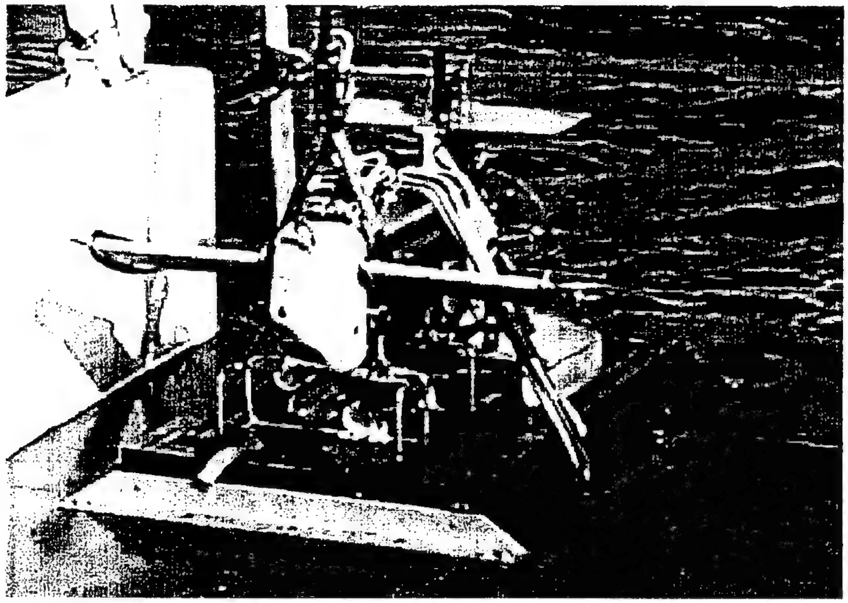


FIGURE 4. Seasoar secured on deck and ready for deployment.

One of the primary limitations in studies of frontal thermohaline and velocity structure has been the inability to resolve the frontal structure with traditional CTD sampling. The SeaSoar vehicle is a towed, winged vehicle (fig 4) which quickly samples the water column. It can resolve thermohaline structure on horizontal scales of 0.5 to 1 km and can sample continuously while steaming at 7 knots (figs 5,6). SeaSoar operations were conducted to measure the thermohaline structure in winter conditions and to compare that with the previous summer experiment. The SeaSoar sampled on a series of grids that roughly encompassed the acoustic transmission paths. Each grid consisted of a series of cross frontal sections separated by 10 km in the along-shelf direction (fig 7). While operations were hindered, as anticipated, by strong winds and rough seas, three complete grids were occupied. Each grid consisting of four cross-shelf transects. Two additional partial grids were also sampled during the six days of SeaSoar operations. SeaSoar sensors measured temperature, salinity, conductivity, fluorescence, transmissiivity and bioluminescence. For more information on the SeaSoar, see website http://matisse.whoi.edu.

TABLE 1. Seasoar operations

deployment 1	2/16/97 1403 -> 2/17/97 0000
deployment 2	2/17/97 1347 -> 2/17/97 1700
deployment 3	2/18/97 0039 -> 2/18/97 1800
deployment 4	2/19/97 1750 -> 2/20/97 0100
deployment 5	2/20/97 1412 -> 2/20/97 2000
deployment 6	2/21/97 0412 -> 2/22/97 0000

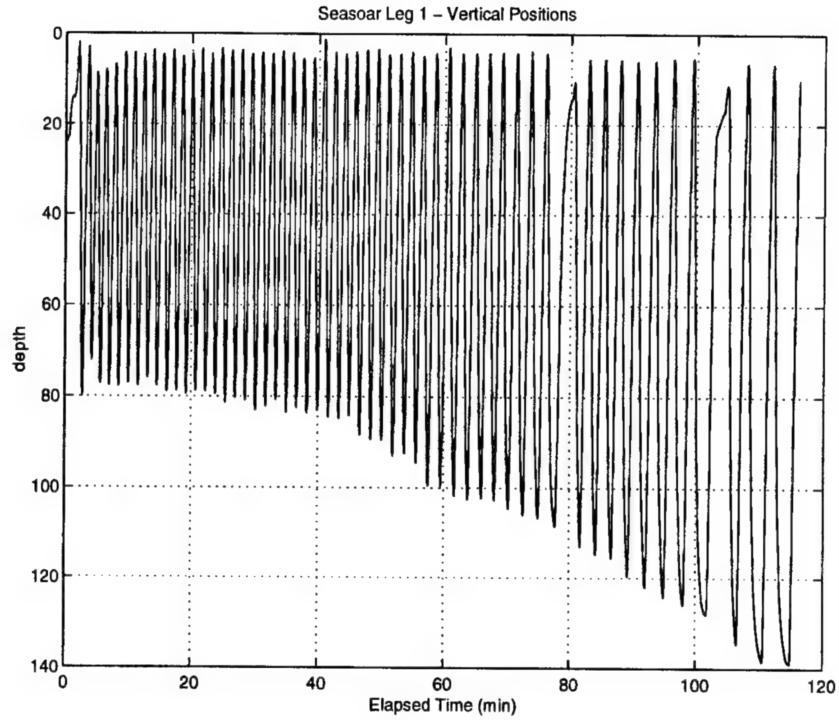


FIGURE 5. SeaSoar undulations for leg 1

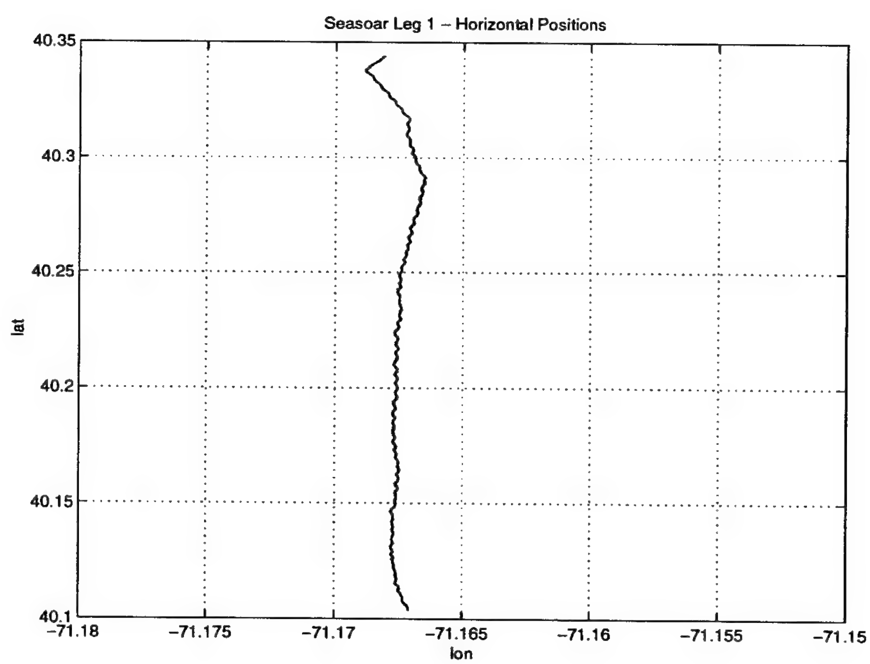


FIGURE 6. Seasoar horizontal locations for leg 1

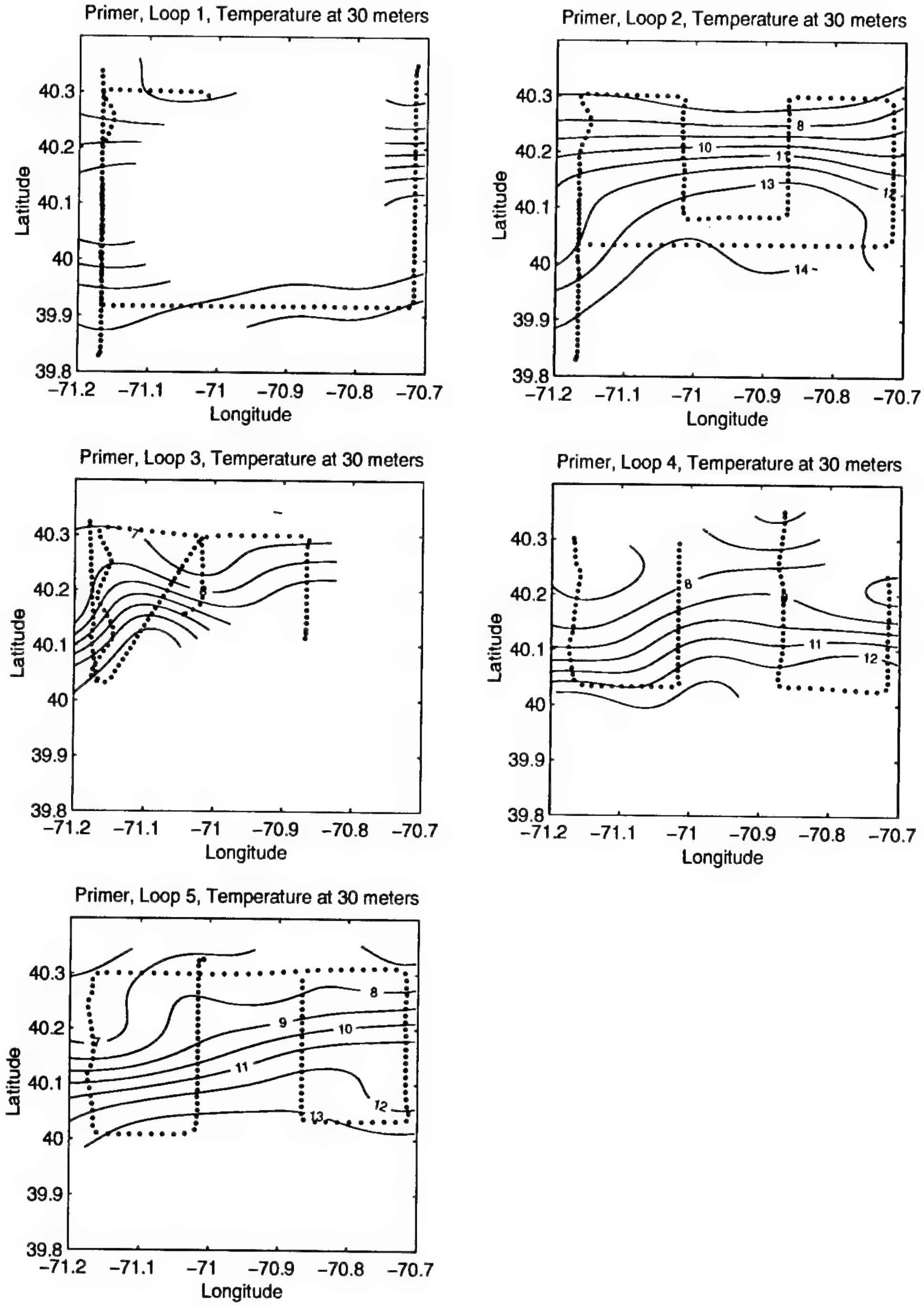


FIGURE 7. Seasoar grids with temperature contours for 30 meter depth.

2.3 Moored ADCP

A moored RDI Instruments, narrow band, self-contained, 300 kHz Acoustic Doppler Current Profiler (ADCP) was moored partway between the SW sources and the WHOI Vertical Line Array (VLA) on the Western leg. The ADCP was attached to the anchor so it sat on the bottom and looked upward (appendix 6.2). The transducer depth was 145 meters. Each vertically sampled velocity bin is 4 meters in length and the depth of the bin is defined by its center (+2 meters from start of bin). The entire water column was sampled with fewer data bins than the ADCP provided. Extra data bins contain irrelevant data and some of the near surface bins contained acoustic reflections that made them useless. Heading corrections, sound speed corrections, and magnitude declination corrections were all enabled.

Data is stored using filenames that are numbered sequentially from the start of logging on Feb. 10, 1997 (i.e 001.dat). The ADCP stayed on deck awaiting deployment for 6 days. The first datafile that contains usable data starts with filename number 016. The data files contain bin number, depth of center of bin, and east, north and upward velocity components. The up/down velocity component was very small (fig 8), roughly 1 cm/sec, and is probably mostly noise. The east and north components at 35 meters (fig 9) show a primarily SE direction. Figure 10 shows the entire water column velocities.

TABLE 2. Moored ADCP

deployed	2/17/97 1014 (Z)
recovered	2/26/97 1610 (Z)
latitude N	40 07.1283
longitude W	71 09.8602
depth (m)	150
logging started	2/10/97 1200 (Z)
sampling interval (min)	1.5
number of pings averaged	225

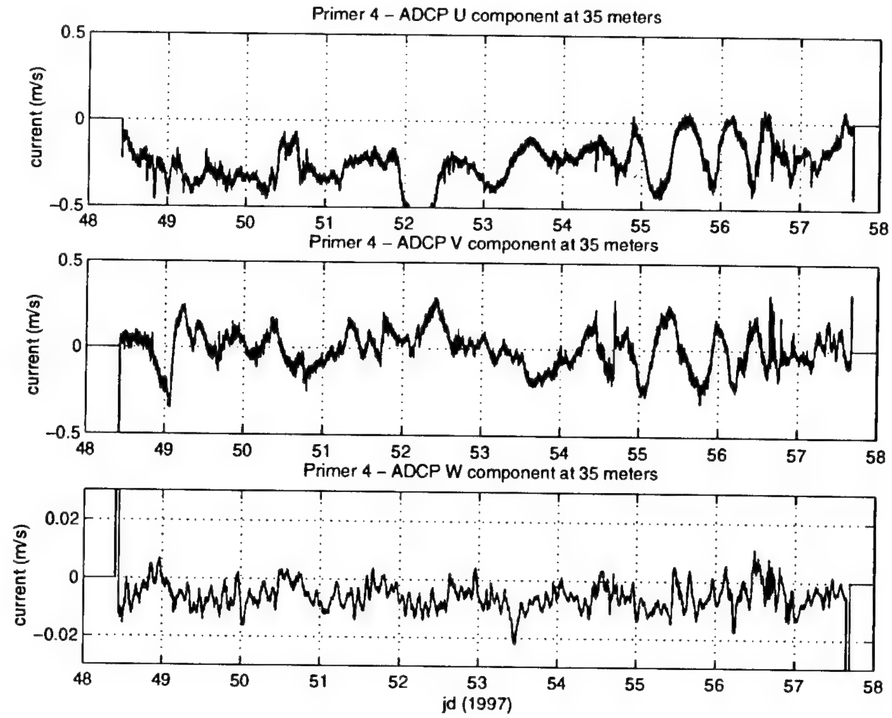


FIGURE 8. ADCP east, west and upward components at 35 meters depth

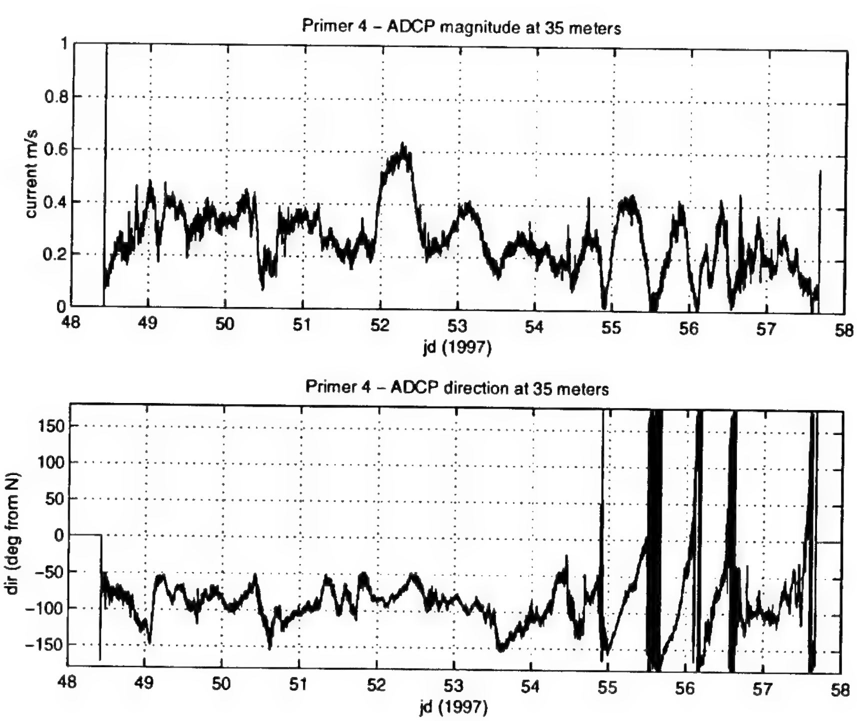


FIGURE 9. ADCP magnitude and phase at 35 meters depth

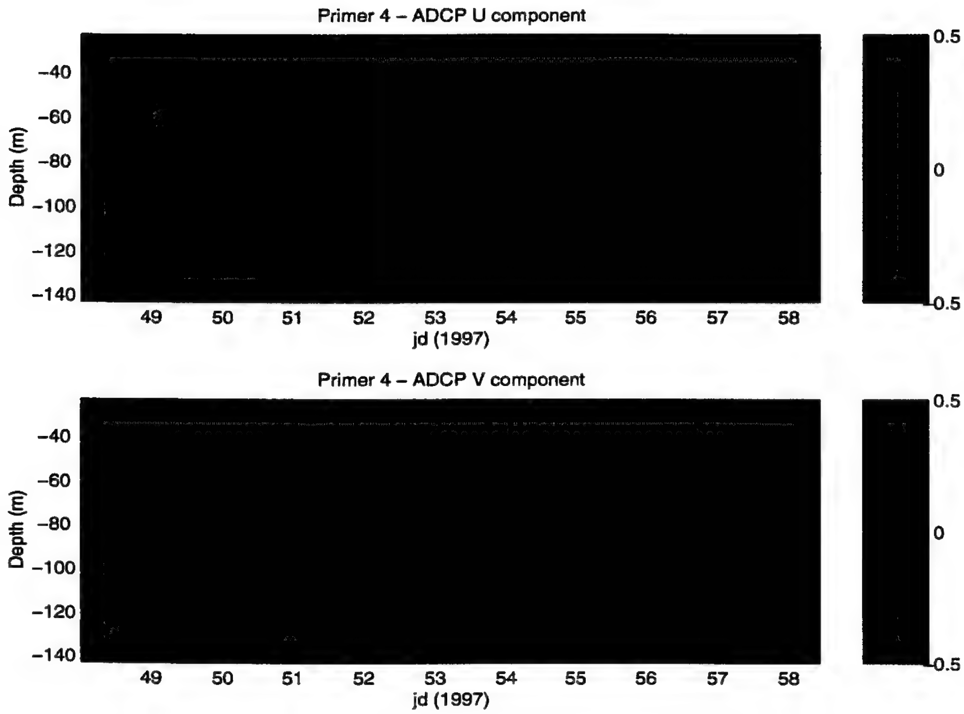


FIGURE 10. ADCP U(eastward) and V(northward) components for entire water column

2.4 Fast-sampling thermistor string

A fast-sampling thermistor string (also see appendix 6.2) was positioned on the western edge of the acoustic field between the WHOI VLA and the SW sources (fig 3) to measure internal waves as they propagated onshore. The T-string sampled temporally every 4 seconds and spatially sampled the water column from 26 meters to 100 meters depths at variable depth increments (see table below). Individual temperature sensors were attached to the mooring at the surface and at the bottom to complete the sampling of the entire water column. Significant subtidal period and internal wave period variability is seen (figs 11-13).

TABLE 3. Fast Sampling Thermistor String

deployed	2/17/97 0827 (Z)
recovered	2/26/97 1755 (Z)
latitude N	40 14.4889
longitude W	71 09.9965
depth	104 meters
sampling interval	4 seconds

TABLE 4. Thermistor Depths

Thermistor	Depth (meters)
t-pod #958	1
# 1	26
# 2	27
# 3	28
# 4	30
# 5	32 (Did not work)
# 6	36 (Did not work)
# 7	40
# 8	44 (Did not work)
# 9	52
#10	60 (Did not work)
#11	68
#12	84
#13	100
#14	101
t-pod #956	102

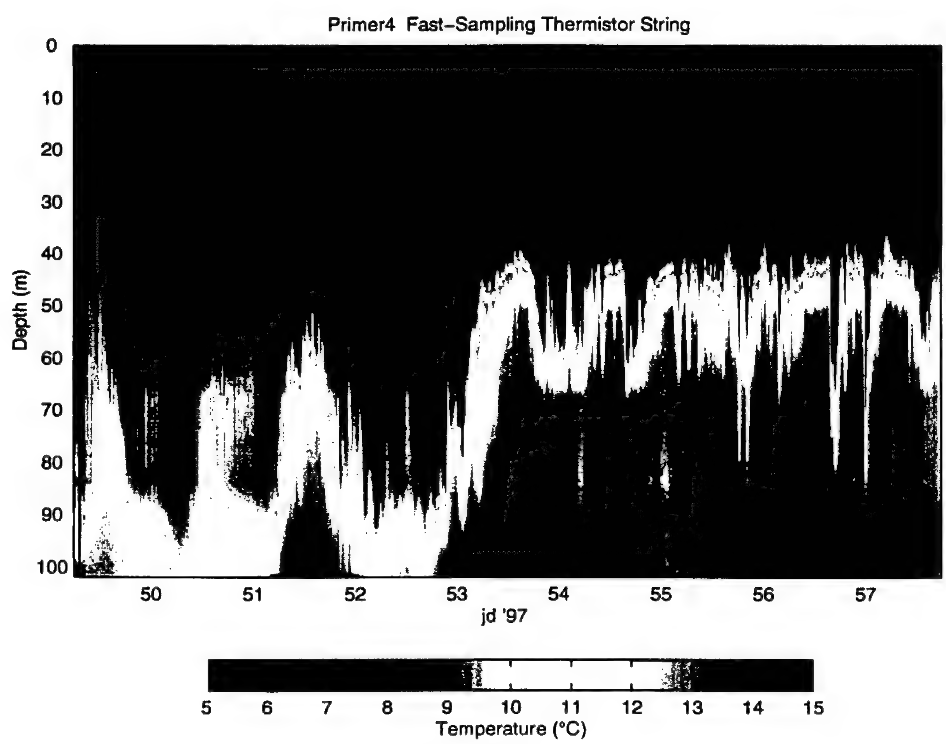


FIGURE 11. Fast sampling thermistor string for entire deployment

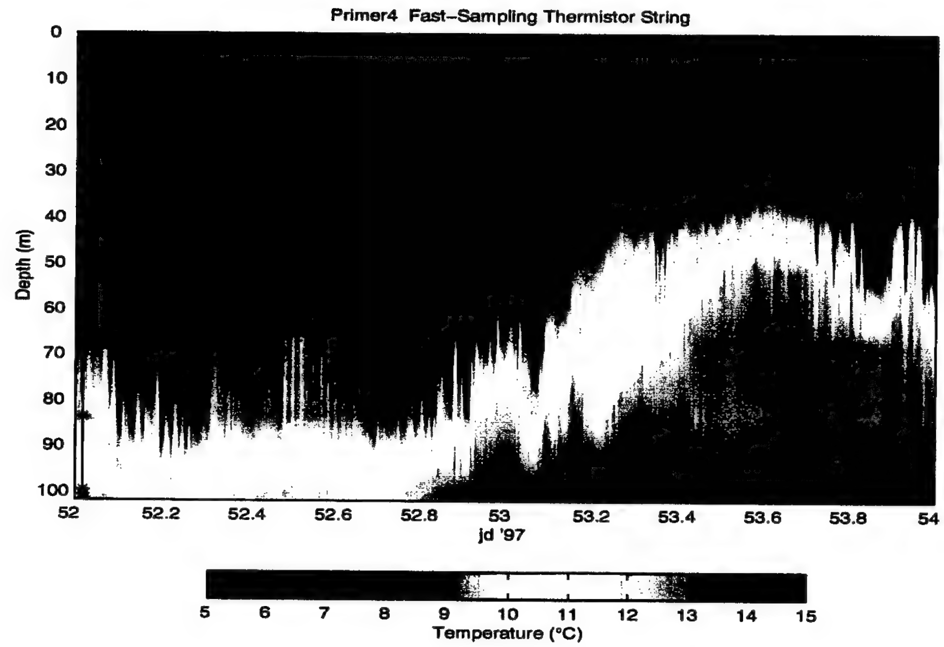


FIGURE 12. Days 53 to 54 from above fast sampling temperature string

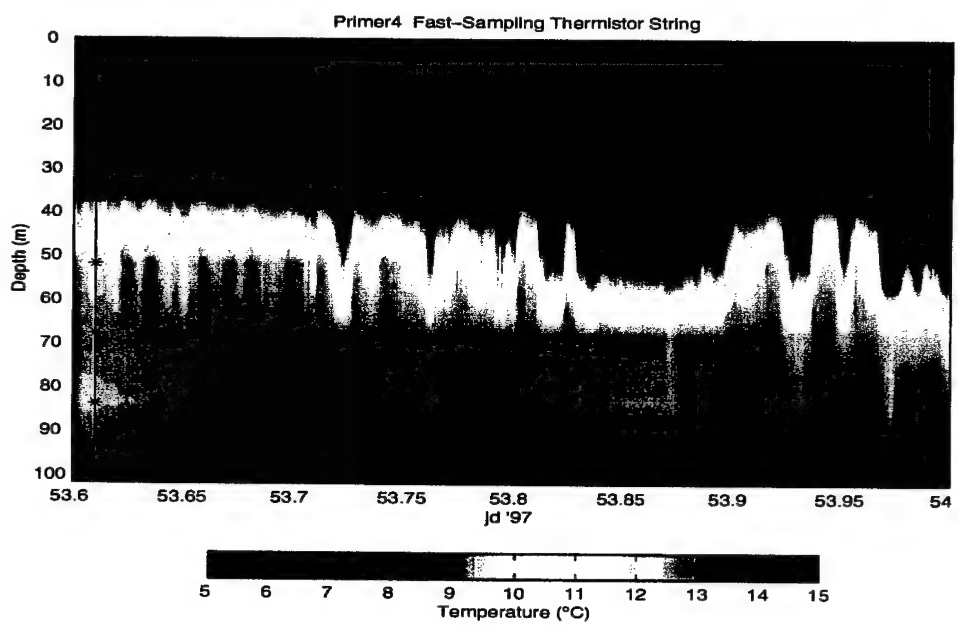


FIGURE 13. Noon to midnight (Z) for day 53

2.5 AXBT's

On Feb 14th, from 1630 to 2200 hrs (local time), thirty five AXBT's were dropped along lines both inside and outside the tomography area (fig 14) to measure temperature on a large spatial scale. While the profiles contained some noise (figs 15,16,,17), the data can be filtered to extract useful temperatures (fig 18) which show frontal temperature following the bathymetry (fig 19) but with a large northbound intrusion at longitude 71.2 degrees W.

TABLE 5. AXBT times and location

time (local)	latitude (N)	longitude (W)
1631	40 42.0000	71 09.3550
1650	40 29.0783	71 23.8250
1705	40 17.8967	71 37.7767
1714	40 42.7750	71 36.9300
1723	40 42.5717	70 40.3983
1730	40 42.0917	70 12.4317
1737	40 28.5350	70 12.2217
1746	40 28.9150	70 56.5583
1810	40 18.1167	71 28.1783
1817	40 16.9000	71 04.9850
1828	40 16.0667	70 55.0000
1835	40 17.2283	70 44.6450
1842	40 17.0383	70 33.5117
1853	40 18.0567	70 12.4717
1900	40 09.7433	70 11.3159
1907	40 09.5533	70 23.7100
1914	40 10.5200	70 33.9583
1938	40 10.7767	70 44.7417
1946	40 11.0267	70 55.0567
1957	40 16.7367	71 05.8233
2012	40 10.7317	71 16.5550
2022	40 01.9350	71 39.5833
2031	40 01.7083	71 26.5150
2042	40 01.5367	71 05.3867
2053	40 01.3967	70 50.8517
2106	40 01.4800	70 44.5300
2116	40 00.9317	70 33.1617
2123	39 59.2083	70 23.4383
2134	40 00.5417	70 12.5383

TABLE 5. AXBT times and location

time (local)	latitude (N)	longitude (W)
2139	39 52.2150	70 12.8467
2145	39 51.4950	70 26.9383
2157	39 51.2283	70 39.7283
2203	39 51.1917	71 09.2417
2211	39 50.9033	71 23.4250
2218	39 51.2767	71 37.6017

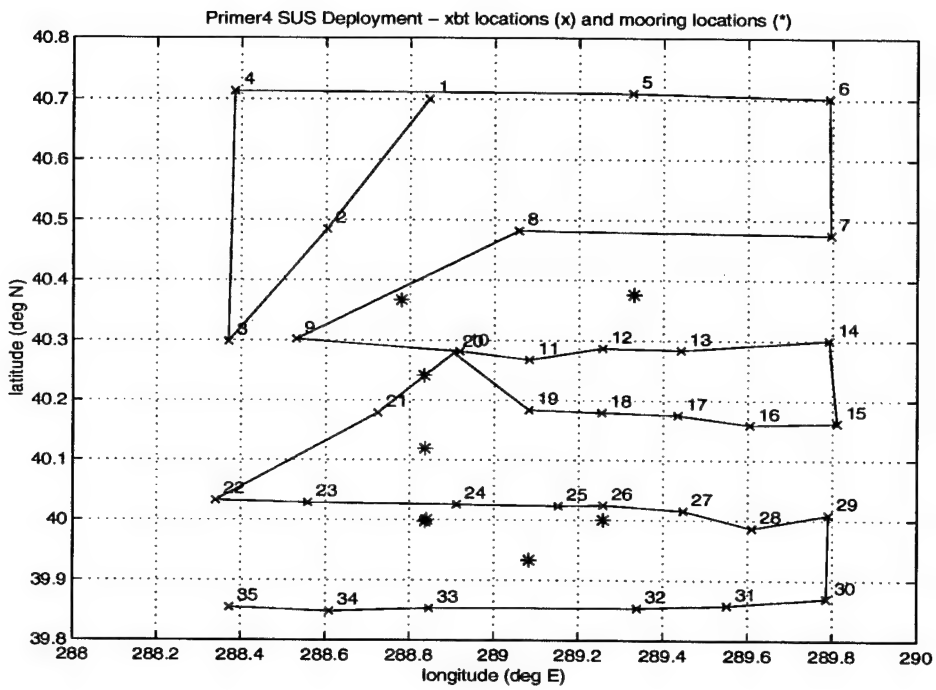


FIGURE 14. AXBT and mooring locations

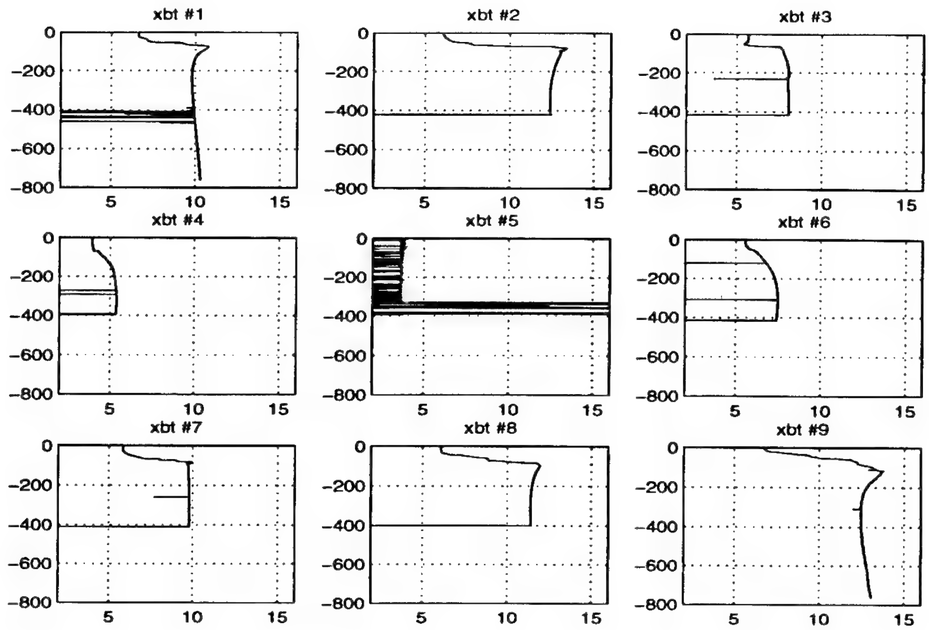


FIGURE 15. AXBT temperature (degrees C) vs depth (m) profiles for drops 1-9.

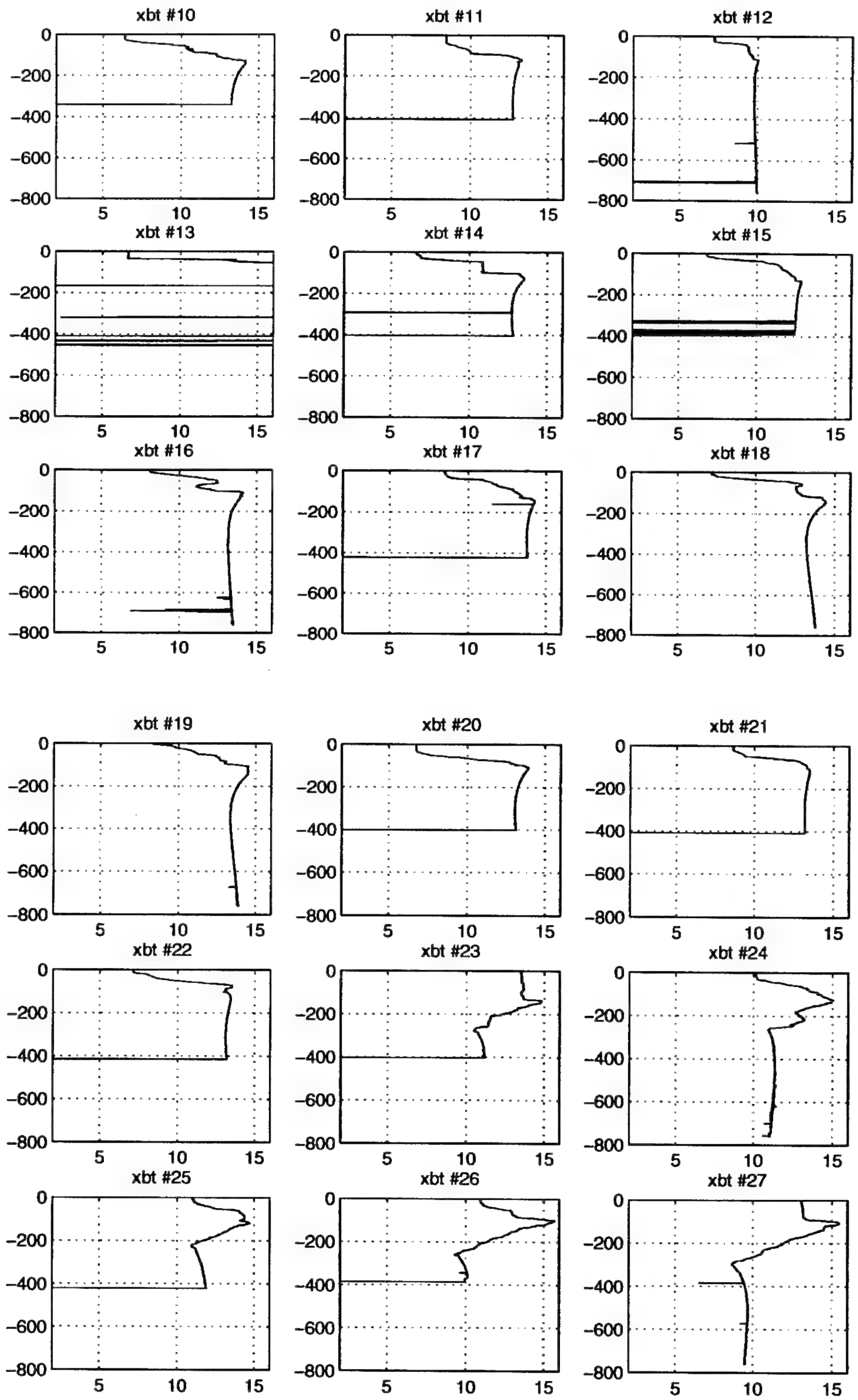


FIGURE 16. AXBT temperature (degrees C) vs depth (m) profiles for drops 10-27.

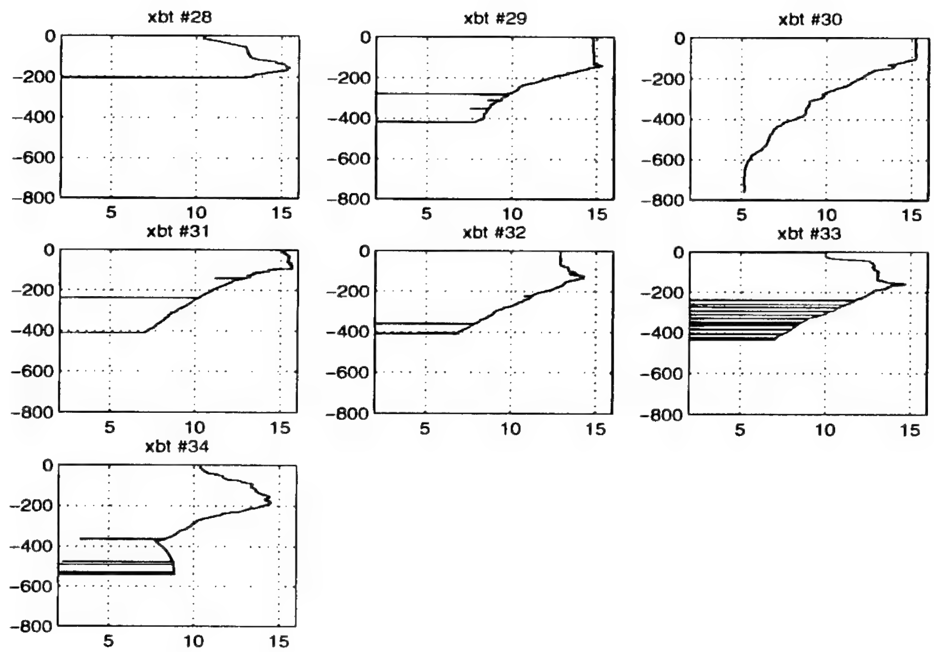


FIGURE 17. AXBT temperature (degrees C) vs depth (m) profiles for drops 28-34

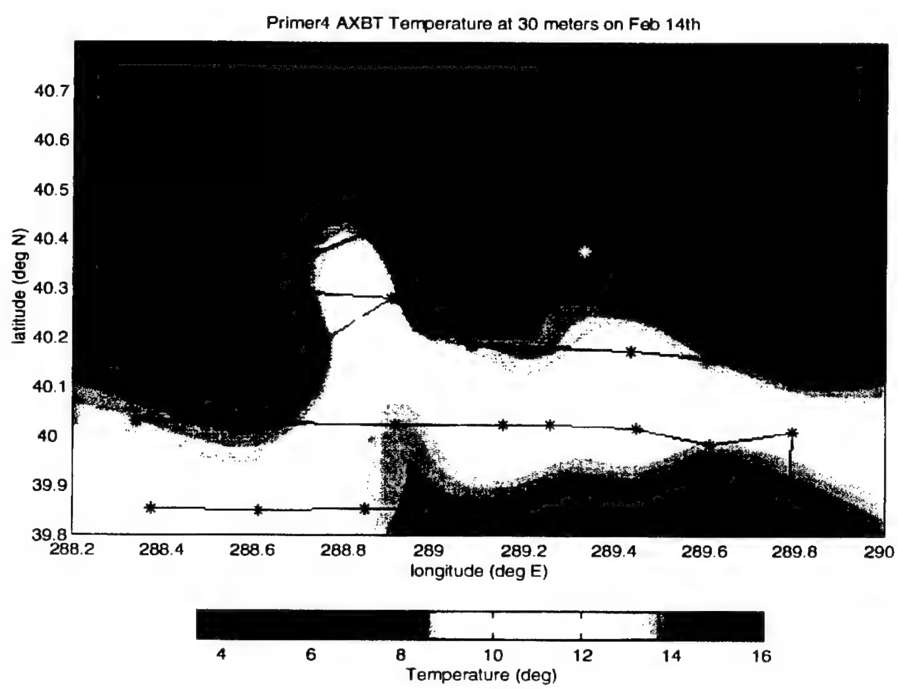


FIGURE 18. AXBT temperature contours at 30 meters depth

TABLE 7. SW mooring hydrophone locations for the short array

Depth (m)	phone - channel
281.05	phone #4 - channel A
281.25	phone #2 - channel B
281.45	phone #3 - channel B
279.38	phone #4 - channel B

TABLE 8. SW mooring Aanderra current meters

Depth (m)	Serial number	Starting time (Z)	Sampling interval
25	9613	Feb 3 @ 1700 hrs	5 minutes
60	10773	Feb 3 @ 1700 hrs	5 minutes
100	9443	Feb 3 @ 1700 hrs	5 minutes

TABLE 9. SW mooring temperature sensors

Depth (m)	Serial number
1	277 (lost)
40	278 (lost)
180	280 (lost)
280	282

TABLE 10. SW mooring acoustic navigation

transponder frequency	latitude (surveyed P3)	longitude (surveyed P3)
11.0 kHz	40 00.2371	71 10.1248
11.5 kHz	39 59.8946	71 10.4039
12.0 kHz	39 59.7938	71 10.0271

TABLE 11. Recovery time check for SW source

Grey Sailclock day hr min sec	Blue Sailclock day hr min sec	System Time day hr min sec
211 12 49 02.874897	211 12 49 02.832565	211 12 49 03
211 12 50 48.874885	211 12 50 48.832474	211 12 50 49
211 12 51 44.874897	211 12 51 44.832475	211 12 51 45

TABLE 12. SYS 11 - SW source mooring transmission schedule

system time (Z) (pre-deployment)	day 37 17 51 14
UTC time (Z) (pre-deployment - grey)	day 37 17 51 14.000017
source Depth (meters)	288.5
transmission times (minutes after the hour)	0,20,40
center frequency (Hz)	400
cycles per digit	4
digits per sequence	511 (10 msec)
number of sequences transmitted	70 (357.7 seconds total)
sequence length	7128
M-sequence law	1533 (Octal)
reception times (minutes after hour)	7,9,13,15,27,29,33,35,47,53,55
number of sequences coherently averaged	12 (61.32 secs)
clock drift (174 days)	.12512 secs

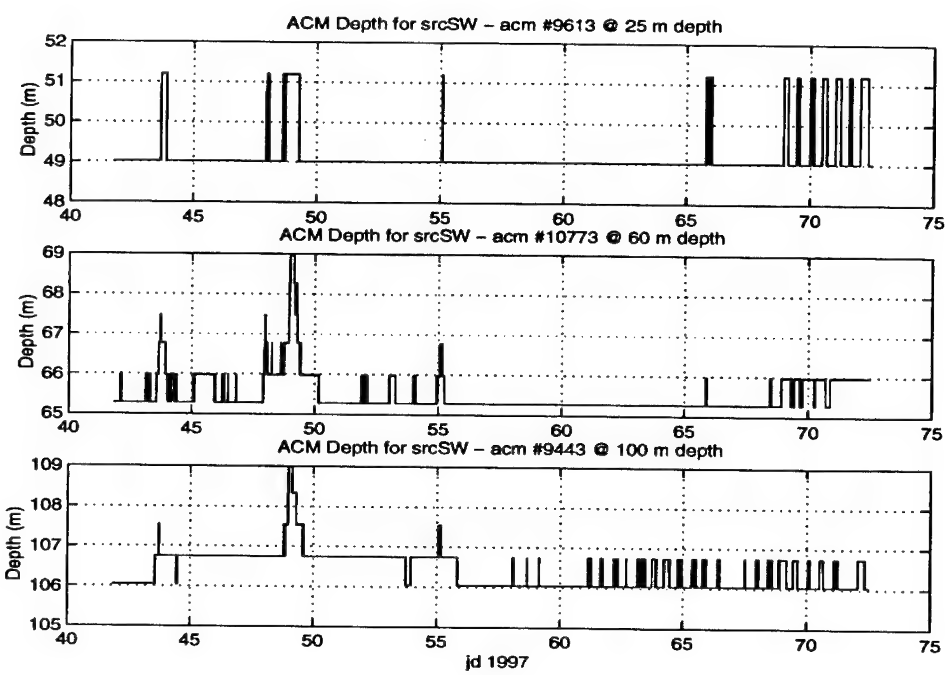


FIGURE 20. ACM recorded depths for SW mooring

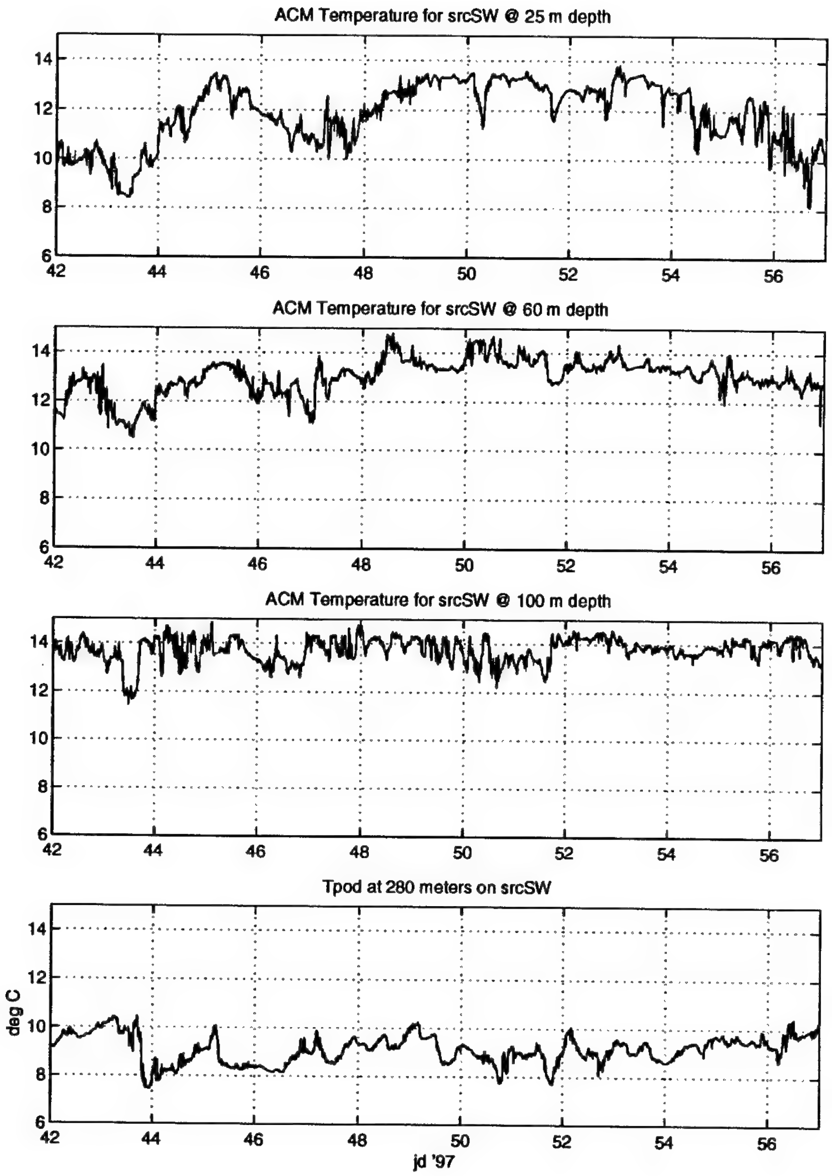


FIGURE 21. ACM temperature at 25, 60, 100 meters and tpod at 280 meters at SW mooring

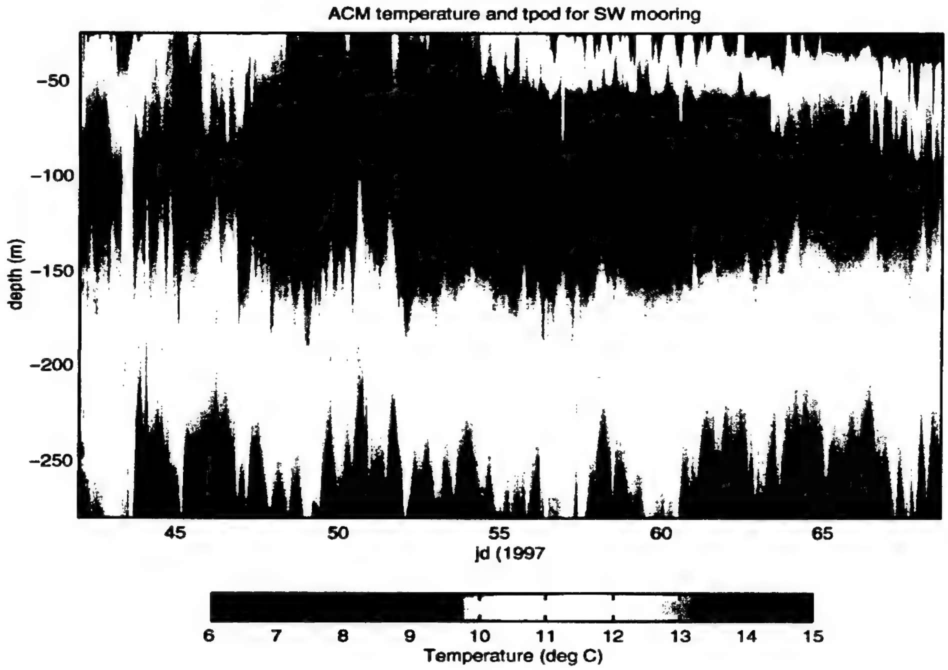


FIGURE 22. ACM temperature for all sensors at SW mooring

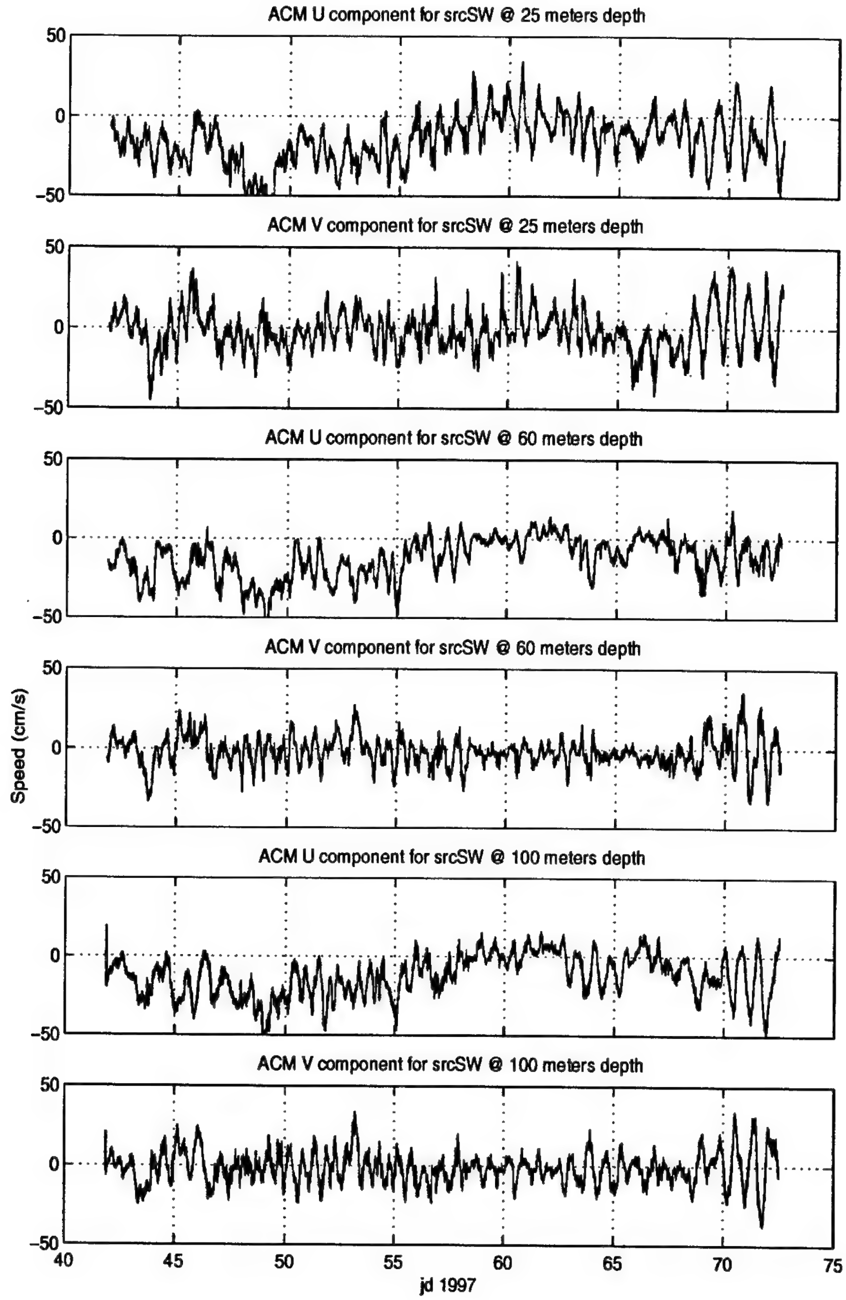


FIGURE 23. ACM U and V components for depths 25, 60, 100 meters at SW mooring

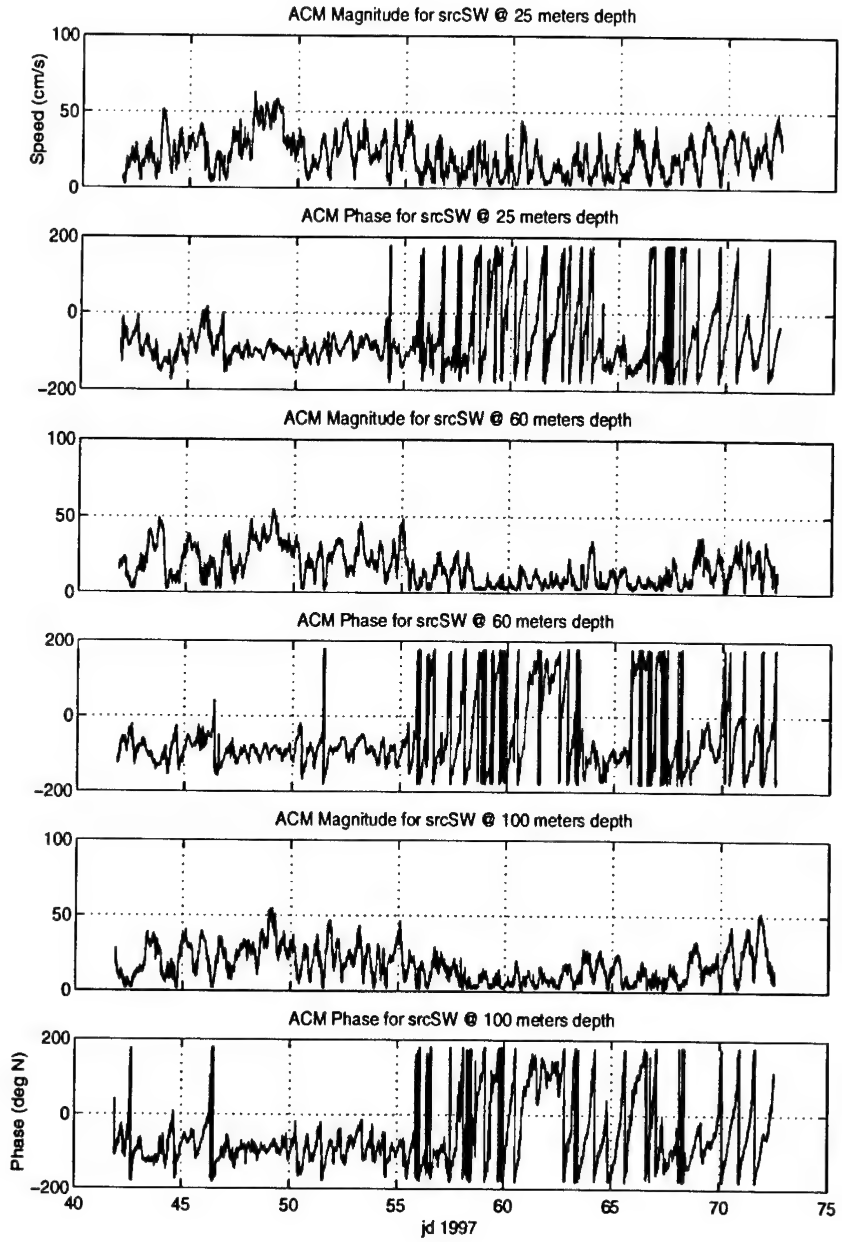


FIGURE 24. ACM magnitudes and phase for depths 25, 60, 100 meters at SW mooring

2.6.2 "C" 400 Hz source and short array mooring

Due to inclement weather, the Central "C" tomography transceiver mooring was recovered during the MOMAX experiment months after the Primer4 experiment ended. From looking at receptions from the "Shark of Science" Vertical Line Array (see VLA section

below), mooring C did not transmit. Data from the short hydrophone array connected to it, however, was recovered and the data is being analyzed by NPS. The internal clock drifted .0212 seconds. The single ACM had depth, temperature and current samples (figs 25,26,27,28). The Central mooring was not navigated for mooring motion due to the short length of the mooring giving a small watch circle.

TABLE 13. Central mooring "C"

system	009
array	014
deployed	2/10/97 0110 (Z)
recovered	3/31/97 1450 (Z)
latitude N	39 56.0390 (surveyed)
longitude W	70 55.0254 (surveyed)
water depth	459 meters

TABLE 14. Central mooring "C" hydrophone array locations

Depth (m)	phone - channel
446	phone #1 - A
443.93	phone #2 - A
444.13	phone #3 - A
444.23	phone #1 - B
442.05	phone #4 - A
442.25	phone #2 - B
442.45	phone #3 - B
440.38	phone #4 - B

TABLE 15. Central mooring Aandera current meters

Depth (m)	Serial number	starting time	sampling interval
427	10769	Feb 3 @ 1700 hrs	5 minutes

TABLE 16. Central mooring transceiver deployment time check

System	Day	hour	minute	second
sys09	041	15	51	36.000000
UTC	041	15	51	35.996039

TABLE 17. Central mooring transceiver recovery time check

System	Day	hour	minute	second
sys09	094	16	37	44.000000
UTC	094	16	37	44.017190

TABLE 18. SYS09 - Central mooring schedule

system time (pre-deployment)	day 37 18 51 57
UTC time	day 37 18 51 56.999988
source depth (meters)	448
transmission times (minutes after hour)	12, 32, 52
center frequency (Hz)	400
cycles per digit	4
digits per sequence	511 (10 msec)
number of sequences transmitted	70 (357.7 secs total)
sequence length	7128
M-seq law	1021 (octal)
reception times (minutes after hour)	.5, 12.5, 20.5, 32.5, 40.5, 52.5
number of sequences coherently averaged	46 (235.06 secs)
clock drift (53 days)	.021151 seconds

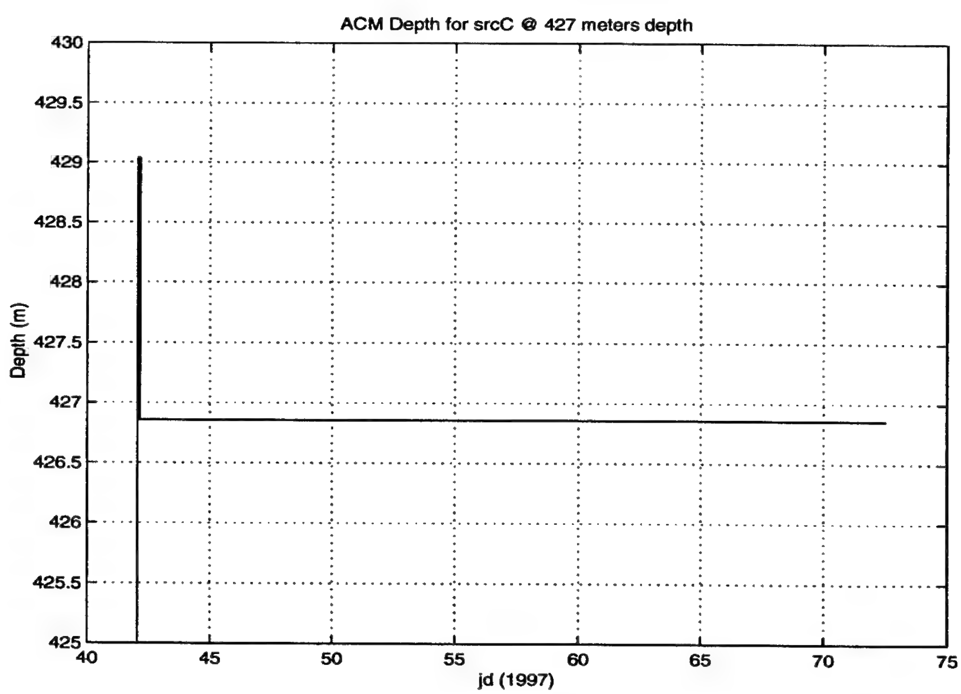


FIGURE 25. ACM depth for mooring C

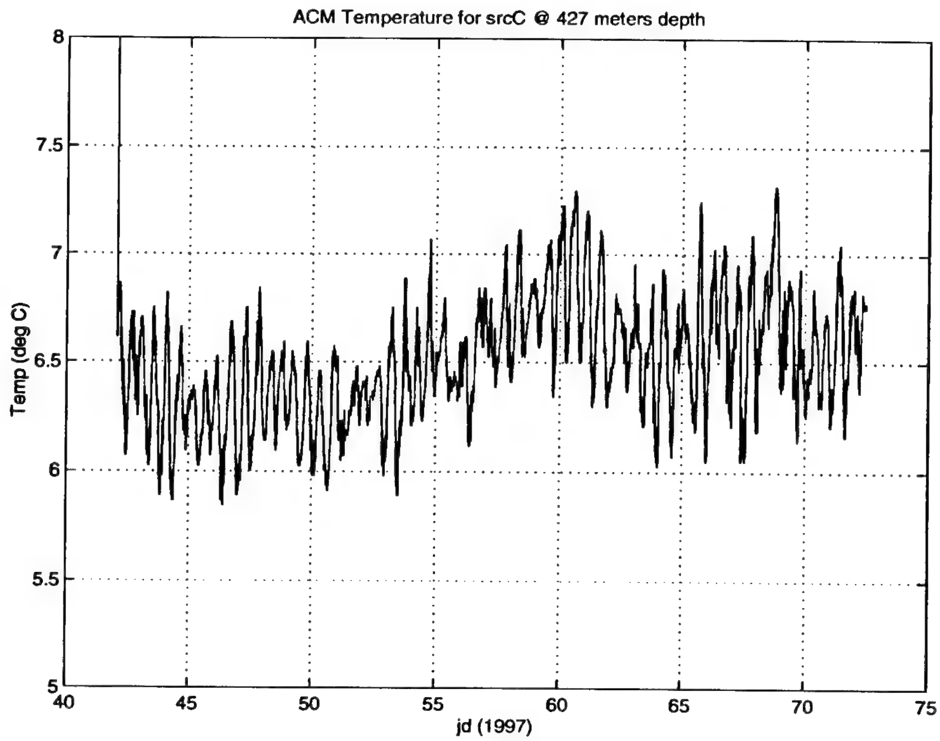


FIGURE 26. ACM temperature at 427 meters depth for mooring C

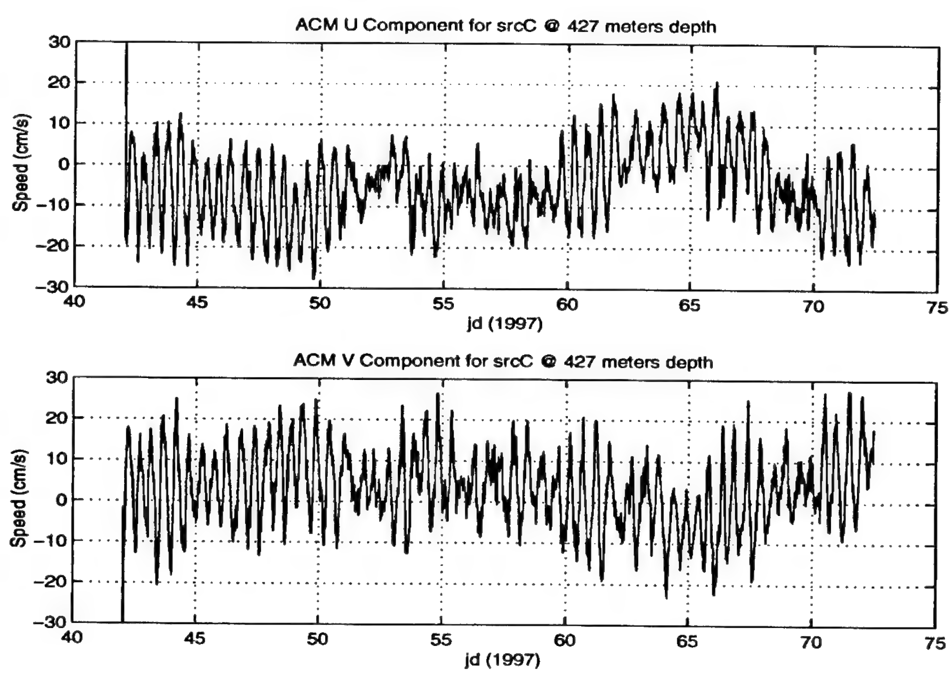


FIGURE 27. ACM U and V components at 427 meters depth at mooring C

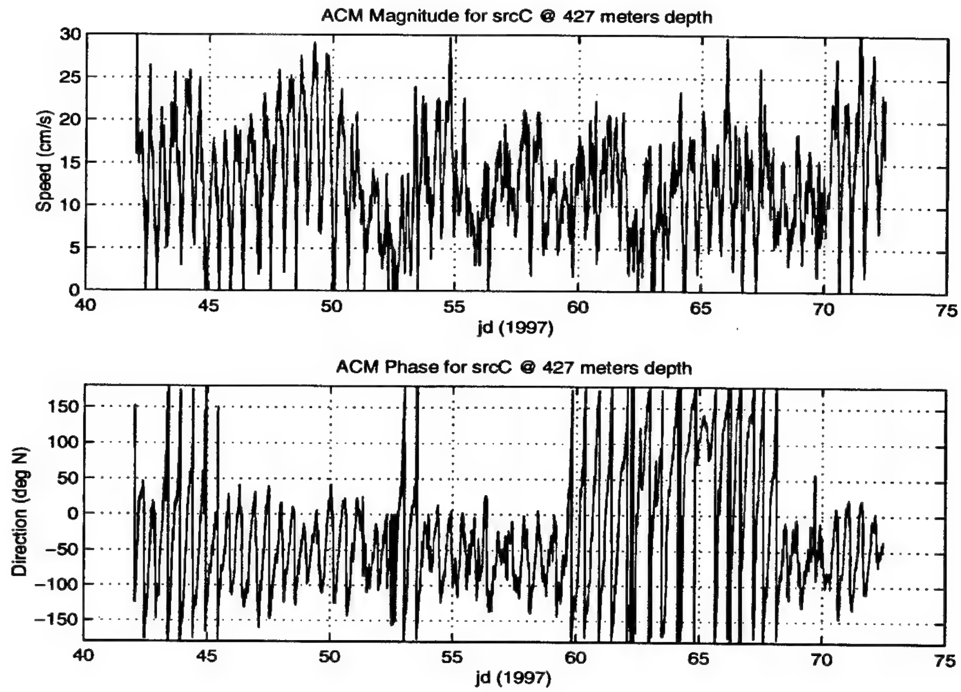


FIGURE 28. ACM magnitude and phase at 427 meters depth at mooring C

2.6.3 "SE" 400 Hz source and short array mooring

Like the other 400 Hz sites, the SE mooring contained a 400 Hz phase encoded source and a short 8 element hydrophone array. Initially, the source was scheduled to have a 70 sequence transmission but instead it used the same 48 sequence transmission that was used previously during Primer3. At recovery, the source was not transmiting due to a leak at the transducer. This failure happened sometime after deployment but the time of failure is unknown at this time. Post-cruise time checks are not available due to this failure.

Using the mooring dimensions and known depth at deployment, the ACM depth should be 247 meters. However, the pressure sensor on the ACM has an average depth of 286 meters (fig 29) which is below the bottom. Given this failure and the failure of the SW mooring ACM, it seems that the ACM pressure sensors cannot be trusted so the depth will be calculated using the mooring diagram (appendix 6.2). Temperature from the ACM can be used (fig 30). The U component of ACM current measurement failed to register negative values (fig 31). Multiple tpods were strapped to the mooring at numerous depths (table 22). Tpod sensors show a clear, deep M2 internal tide signal.(figs 32, 33). Since one of the tpods was strapped to the ACM, a comparison shows that both sensors are calibrated correctly (fig 34).

TABLE 19. SE mooring

system	013
array	010
deployed	2/10/97 0414 (Z)
recovered	2/26/97 0630 (Z)
latitude N	39 59.9956 (surveyed)
longitude W	70 44.4883 (surveyed)
water depth	279 meters

TABLE 20. SE mooring hydrophone array #010 locations

Depth (m)	phone - channel
259	phone #1 - A
256.90	phone #2 - A
257.13	phone #3 - A
257.33	phone #1 - B
255.05	phone #4 - A
255.25	phone #2 - B
255.45	phone #3 - B
253.38	phone #4 - B

TABLE 21. SE mooring Aanderra current meter

Depth (m)	Serial number	starting time	sampling interval
247	9445	Feb 3 @ 1700 hrs	5 minutes

TABLE 22. SE mooring temperature sensors

Depth (m)	Serial number
1	283
100	285
200	290
247	291
275	294

TABLE 23. Sys 013 - SE source mooring transmission schedule

system time (pre-deployment)	day 37 17 51 14
UTC time	day 37 17 51 14.000017
source depth (meters)	257
transmission times (minutes after hour)	6,26,46
center frequency (Hz)	400
cycles per digit	4
digits per sequence	511 (10 msec)
number of sequences transmitted	70 (scheduled) 48 (actual)
sequence length	7128
M-seq law	1175 (octal)
reception times (minutes after hour)	1, 3, 13, 15, 21, 23, 33, 35, 41, 43, 53, 55
number of sequences coherently averaged	n/a

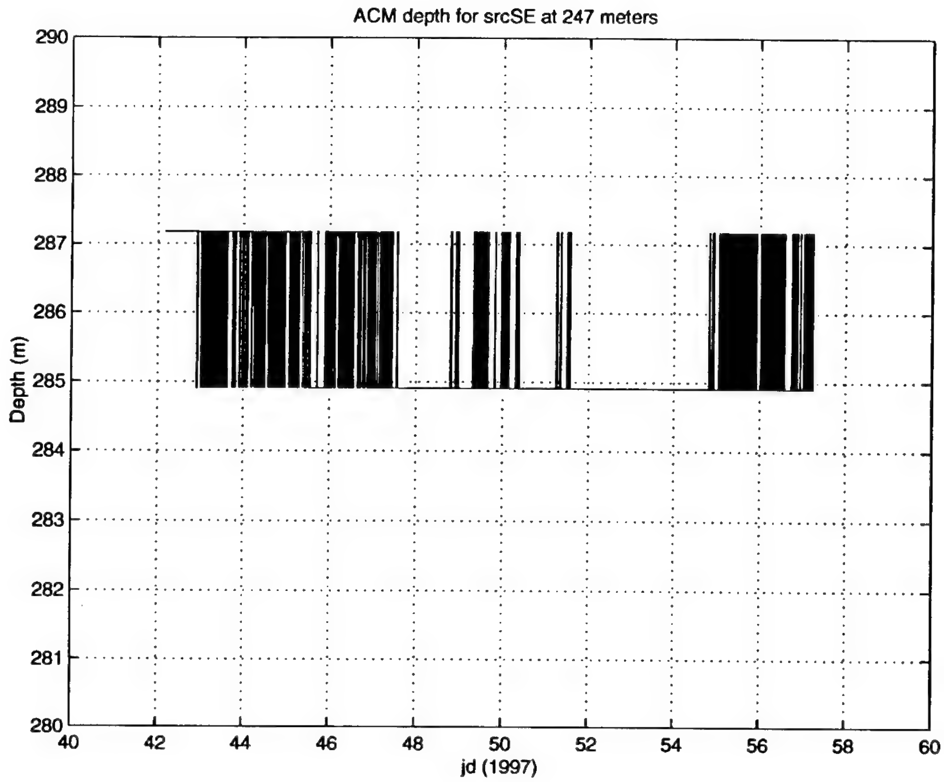


FIGURE 29. ACM depth sensor at 247 meters for mooring SE

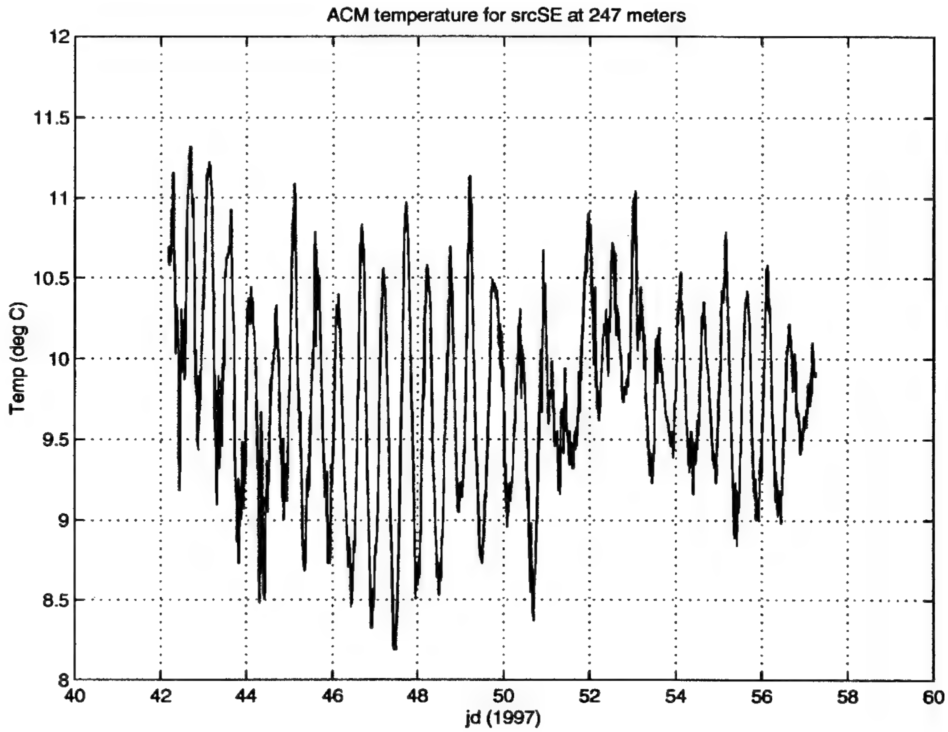


FIGURE 30. ACM temperature at 247 meters depth for mooring SE

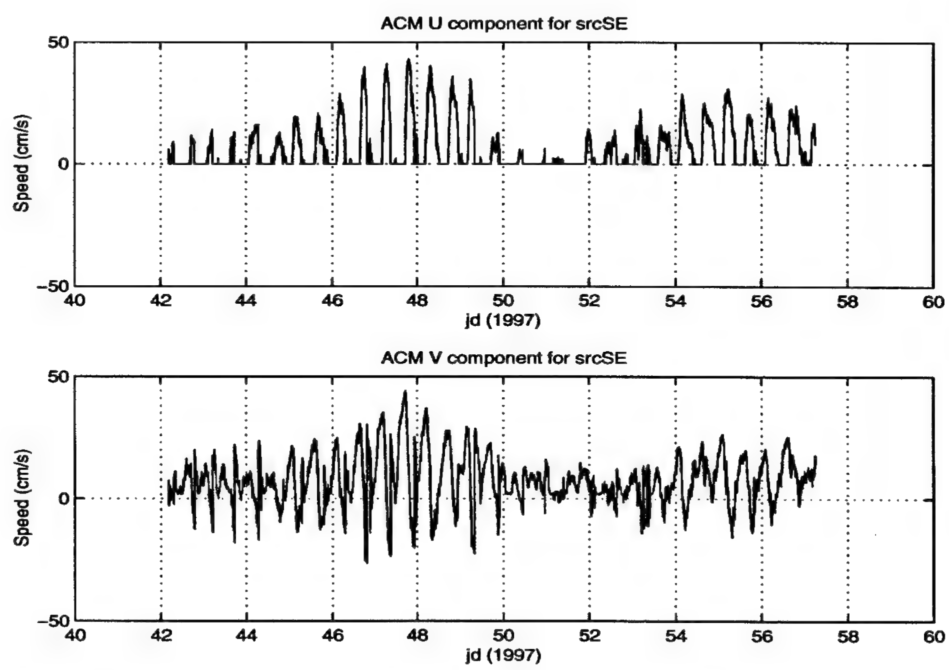


FIGURE 31. ACM U,V components at 247 meters depth for mooring SE

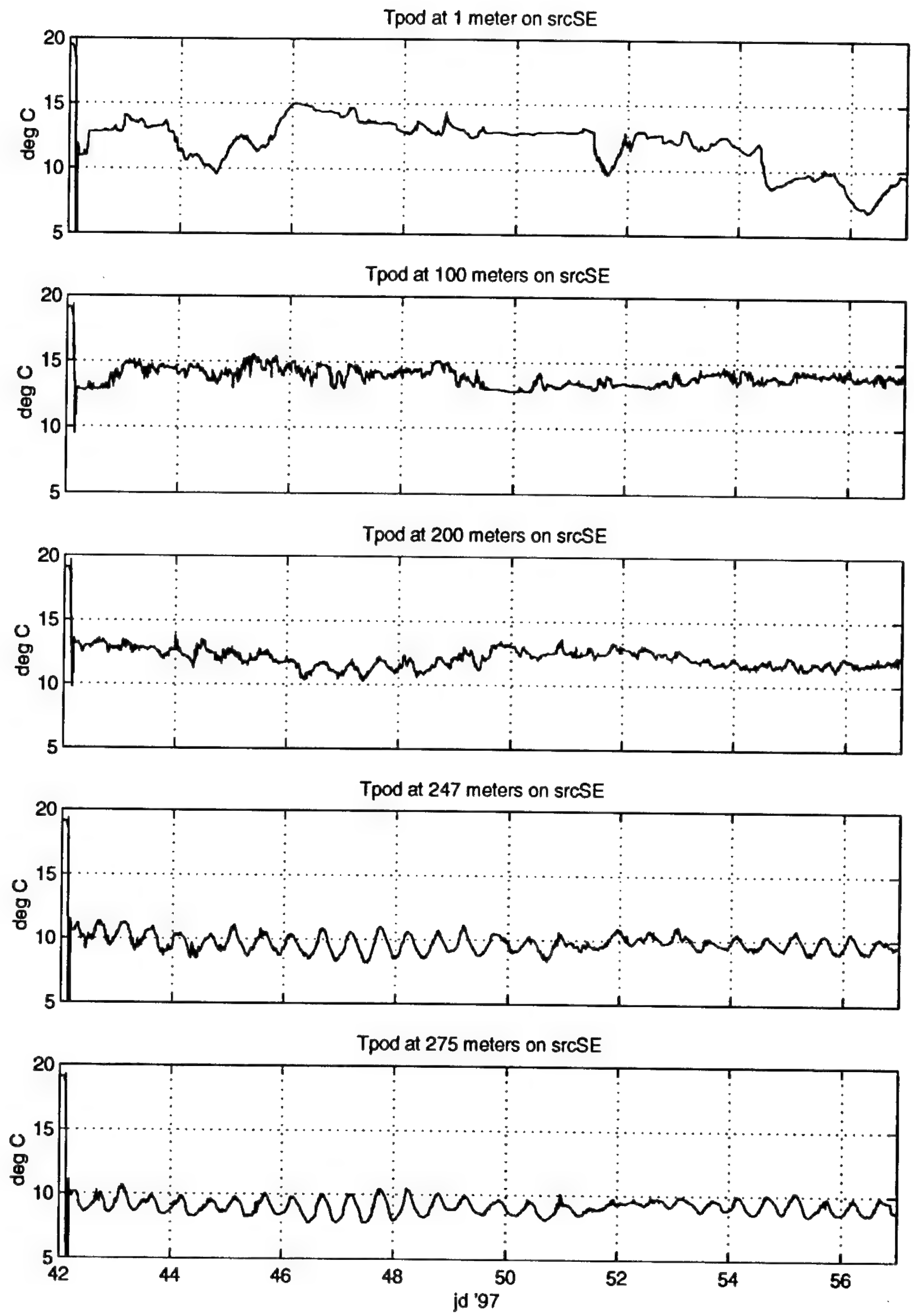


FIGURE 32. Tpod temperature sensors on mooring SE

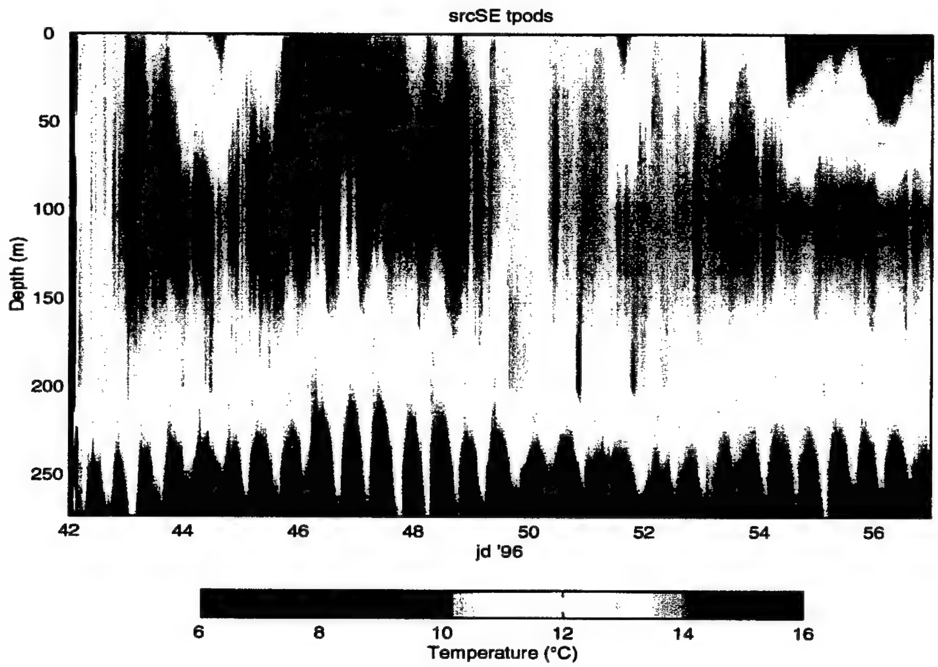


FIGURE 33. All tpod sensors on mooring SE

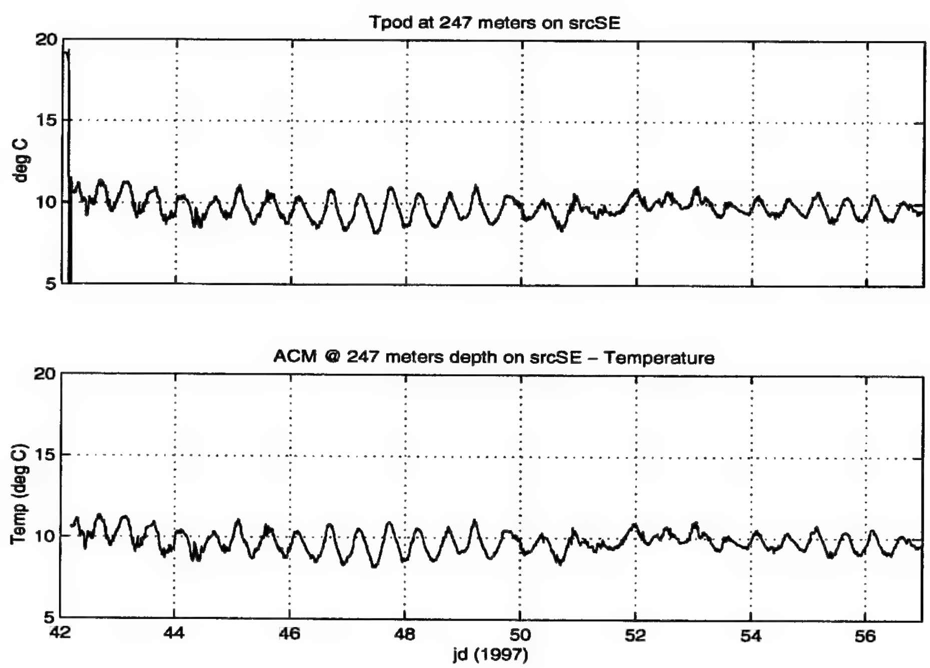


FIGURE 34. Comparison of temperature from tpod and ACM at same depth for SE mooring

2.6.4 224 Hz source mooring

To compare multiple frequency propagation along the same paths, a 224 Hz phase encoded Webb source was positioned near the SW 400 Hz source site. As in many experiments before, this source performed flawlessly. The internal clock for the 224 Hz source was inadvertently started 10 seconds too soon, thus making all scheduled transmissions 10 seconds early. Later in the cruise, the surface float at this site disappeared along with Seamon tpod #256, probably cut by a fishing vessel. Since the temperature sensor #7050 data didn't seem to span the entire deployment (fig 35), a closer look was necessary. When compared to the close 400 Hz SW source mooring, there seems to be a 1 day dropout on Feb 27th, day 56.25 (fig36). This temperature data will need more attention at a later date.

TABLE 24. 224 Hz Source "Bertha"

deployed	2/10/97
recovered	7/19/97 (summer pickup)
latitude N	40 00.036036 (surveyed)
longitude W	71 09.67715 (surveyed)
depth (m)	282

TABLE 25. "Bertha" transmission schedule

system time (pre-deployment)	day 41 11 24 00
UTC time	day 41 11 24 59.999512
source depth (meters)	277
transmission times (minutes after hour)	0,5,10,... every 5 minutes (with 10 sec error)
center frequency (Hz)	224
cycles per digit	14
digits per sequence	63
number of sequences transmitted	30 (3.9375 sec total)
sequence length	5493
M-seq law	0103 (octal)
clock drift (sec)	.637986

TABLE 26. 224 Hz source mooring - temperature sensors

depth (m)	sensor
1	#256 tpod (lost)
270.5	#7050 Brankner

TABLE 27. Recovery time checks

Grey Sailclock day hr min sec	**Blue Sailclock** day hr min sec	**System Time** day hr min sec
211 11 49 49.361526	211 11 49 50.401714	211 11 50 00
211 11 54.49.361158	211 11 54 50.401707	211 11 55 00

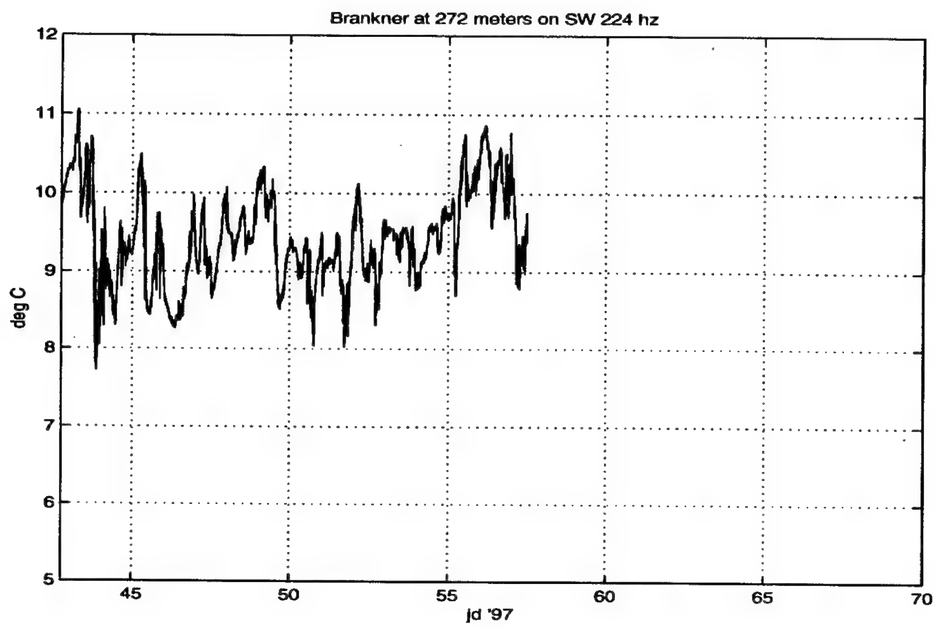


FIGURE 35. Brankner temperature sensor at 272 meters depth on 'Bertha'

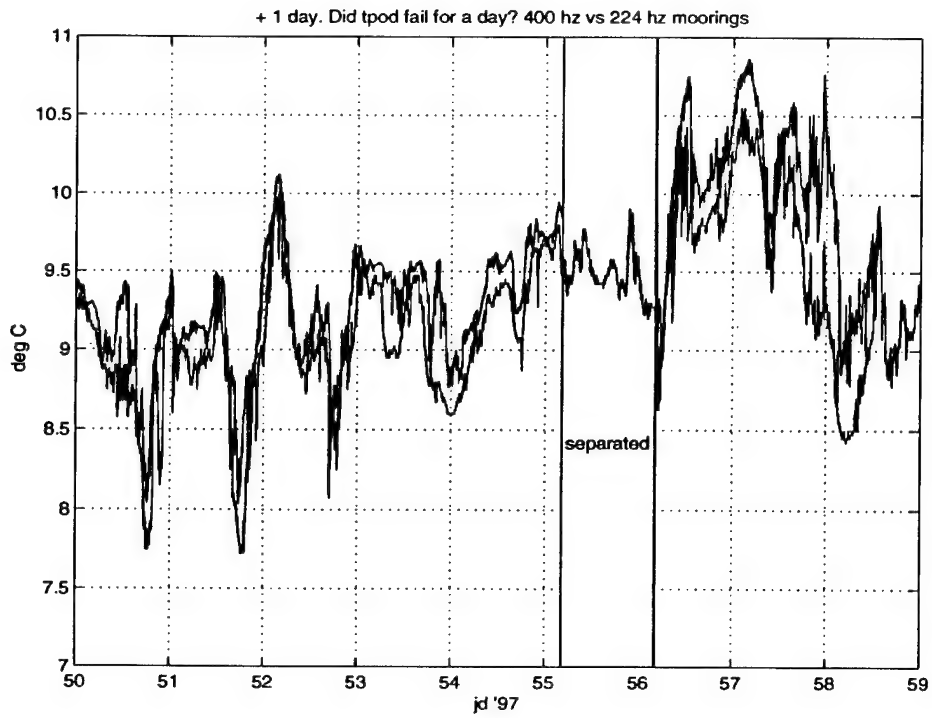


FIGURE 36. Comparison of temperature sensors at same depth for Bertha and mooring SW shows a 1 day failure for the Brankner sensor.

2.7 Acoustic receiver vertical and horizontal line arrays

Line hydrophone arrays were deployed in the Northwest and Northeast corners of the Primer4 area of study (fig 2). Sensor spacing was chosen to adequately sample the modal propagation field. The WHOI VLA in the northwest corner had a surface mooring for telemetry capabilities in addition to internal storage of data while the "Shark of Science" VLA in the northeast corner only internally recorded data (see appendix 6.1).

Ocean acoustic tomography requires very accurate measurements of range between source and receiver for determining changes in arrival times. Without accurate positioning, mooring tilt, due to currents and tides, could be confused as an oceanographic feature by altering range, and thus travel time, between source and receiver. All data needs to be corrected for the effects of mooring motion before subsequent processing can proceed. To navigate the WHOI Vertical Line Array, 3 Benthos transponders were positioned on the seafloor at approximately 1 km from the mooring's anchor forming a triangle surrounding the mooing. The transponders were also positioned at slightly different distances from the mooring so that the acoustic responses would not interfere with each other. Two hydrophones on the WVLA and an independent navigator attached to the mooring were used for recording the position navigation receptions.

2.7.1 WHOI Vertical Line Array (WVLA)

Temperature sensors were strapped on the WHOI VLA at critical depths to sample the water column temperature field (figs 37 38).

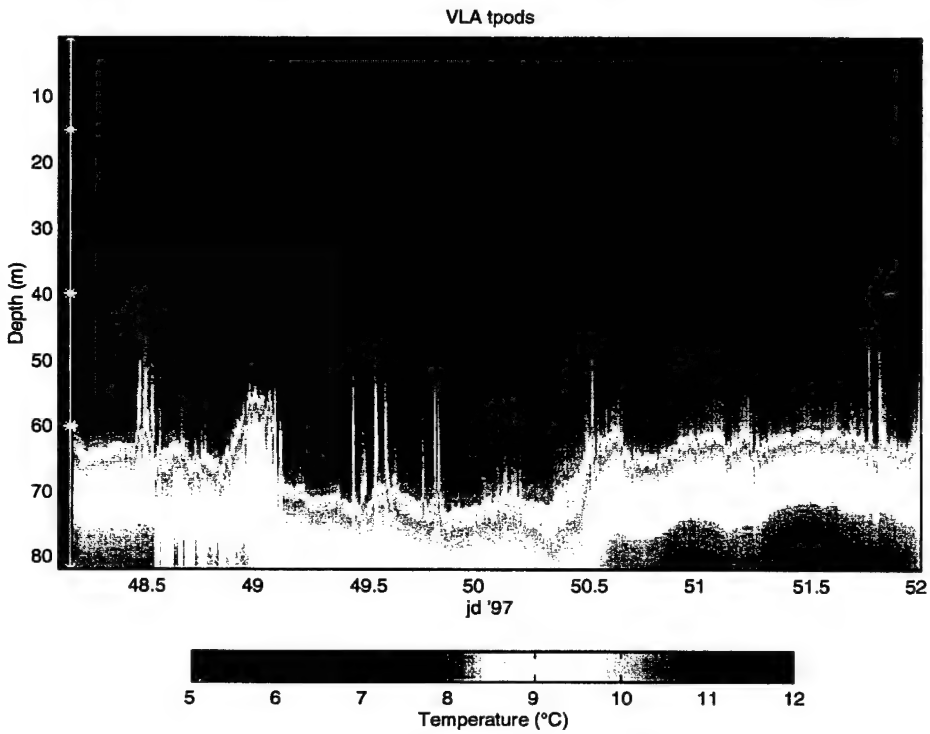


FIGURE 37. VLA tpod temperature sensors

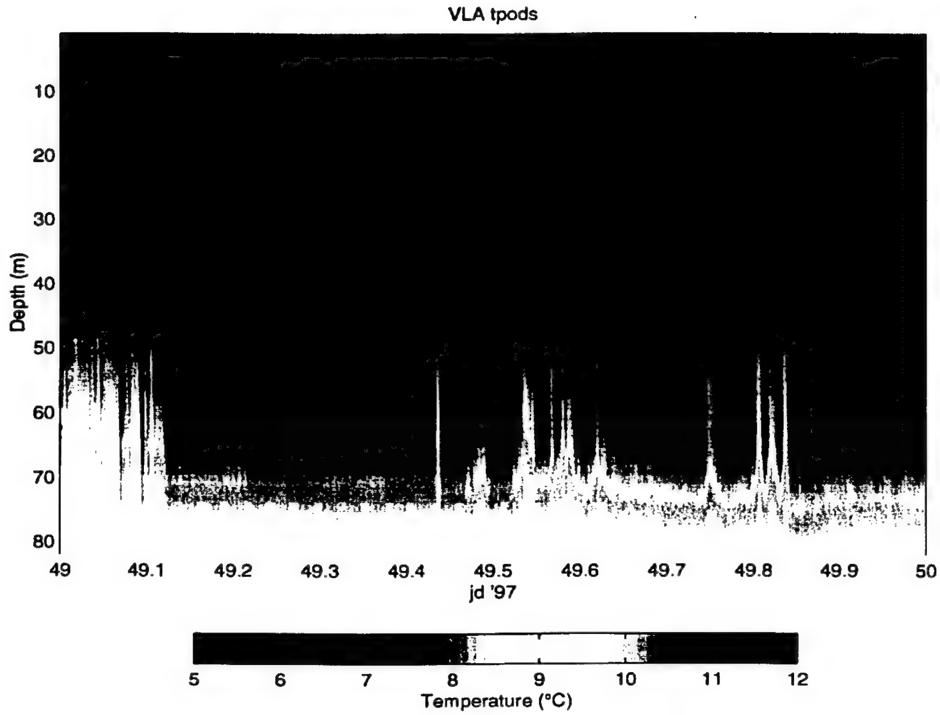


FIGURE 38. Blowup of VLA tpods to show 1 day and internal wave activity

The WVLA was deployed in the same approximate location as it had been during the previous summer's Primer3 experiment to reuse the transponders for determining mooring motion that were left there previously. They were resurveyed and it was found that the 12.5 kHz transponder was missing. An 11.5 kHz transponder was deployed in its place. The frequency change was necessary so that there would be no interference if the missing 12.5 kHz transponder unexpectedly became active again.

The day before departure from port the hydrophone array was again tested for reliability. Much to everyone's surprise, the array failed. The termination to the electronic package was refitted but still failed to work. An older array once deployed in the Barents Sea was used instead. The alternate hydrophone array was designed for deeper water so the length and spacing on this array was longer. Instead of having 3.3 meter hydrophone spacing and spanning 30 meters vertically, the array had 10 meter spacing and spanned 150 meters. To fit it for shallower water, the hydrophone in the center of the array was removed and the termination to the electronics package was made there. Spatial sampling of the water column was now more coarse than originally intended but this design added another feature, an 8 element horizontal array. All phones worked after deployment; however a few failed within a couple of days probably due to the strain from bad weather (fig 39). The horizontal array ran approximately 90 degrees West (fig 40) from the anchor.

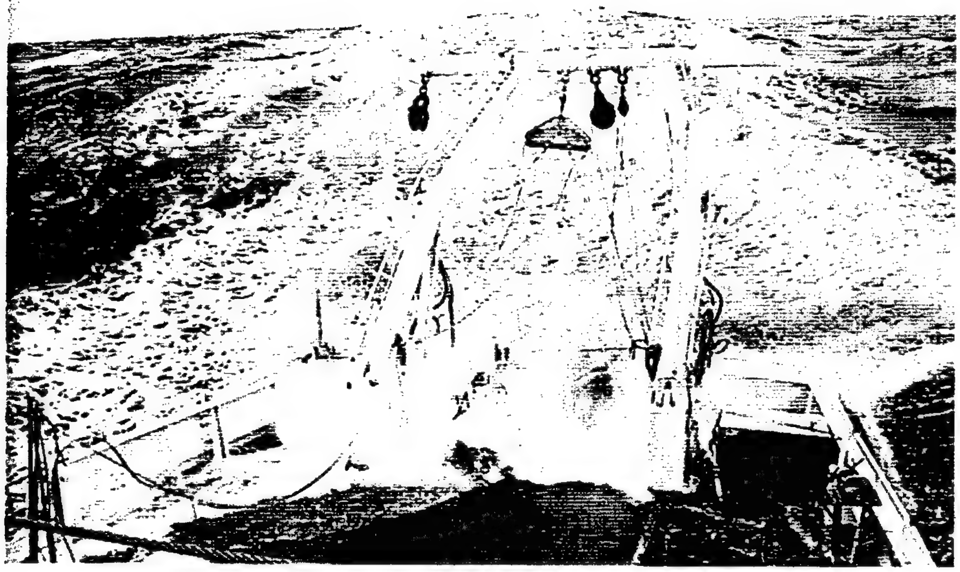


FIGURE 39. Large wave ready to break over the fantail.

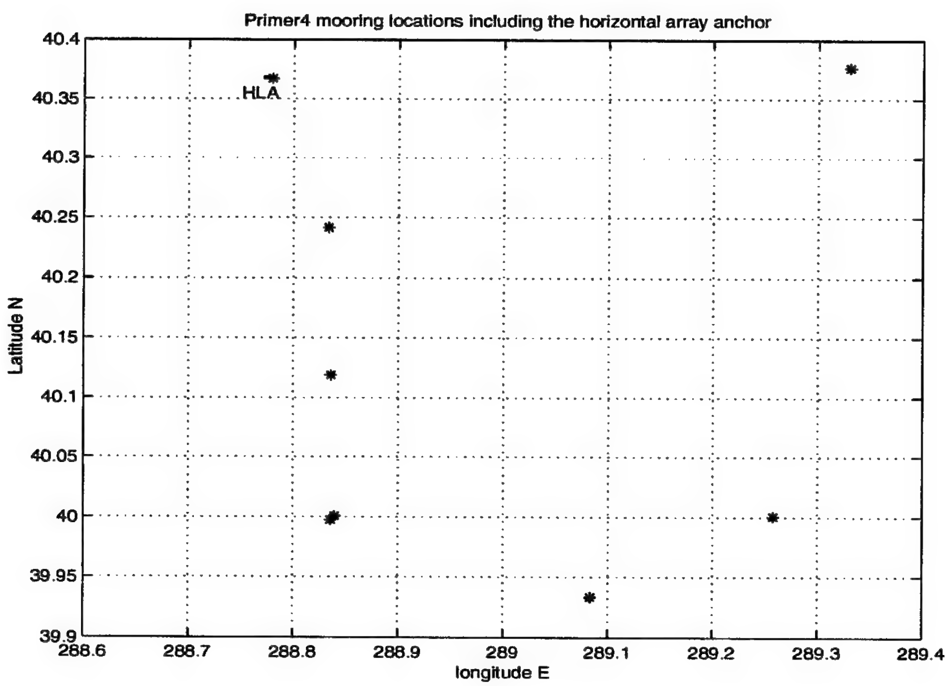


FIGURE 40. Horizontal hydrophone array positions

WVLA phones 0 and 6 were used for taking mooring navigation data at times when the sources were quiet, but that data was very sporadic and thus not useful. An external navigator was also used (fig41). One channel was very noisy but the other two channels are good enough to use for navigation.

Problems with the array started as time went on and the weather deteriorated. All hydrophones worked after deployment on Feb. 17, but by Feb 19, only 2, 10, and 12 seemed to be still functioning properly.

Channel 2 of the VLA worked consistently throughout the experiment. Three datafiles were chosen for spectral analysis. The datafile on Feb 27 at 0646 hours (GMT) was the first full file just after deployment. Source arrivals are easily seen in a spectrogram of channel 2 of this datafile (fig 42). The 224 Hz and 400 Hz sources are evident as well as a bit of low frequency broadband ship noise. Also notice that only 2 of the 400 Hz sources were working leaving a gap after 2 consecutive responses. 400 Hz source at the Central mooring which was scheduled to "sing" at 6, 26 and 46 minutes past the hour did not transmit any sound. The spectrum of record 267 (fig 43) for unprocessed (raw) data shows the 244 Hz source well above (20 dB maximum) the noise level. All hydrophones were working at this time (figs 44, 45, 46, 47).

Spectrogram of channel 2 of the VLA datafile on Feb 29 at 2001 (GMT) (fig 48) shows a clear signal of the 400 and 224 Hz sources with some low frequency noise. Since the propagation path of the source at mooring SE was longer than the moorings at the SW corner, some of the signal is lost in the noise. At this time some of the degradation of hydrophones 0,1,3,4,5,6,8,9,11,13,14,and 15 has started (figs 49 - 52). Only channels 2, 12, and possibly 10 show no wear. Recall that the weather was becoming extremely violent, which was probably the reason for the degradation of the hydrophones.

The datafile on Feb 22 at 1030 hours contained data near the end of the deployment. Although the sources were still operating at this time, source levels can barely be seen above the noise (fig 53). Also notice that some of the hydrophones that previously were noisy probably have some usable data (figs 54-57). Phones 0, 2,10,11, and 12 in particular look good.

TABLE 28. WHOI VLA

deployed	2/17/97 0445 (Z)
recovered	2/22/97 0200 (Z)
latitude (array)	40 22.0848 (surveyed)
longitude (array)	71 13.7329 (surveyed)
water depth	83 meters

TABLE 29. WHOI VLA temperature sensors

Depth (m)	Serial number
1	953 (high flyer)
1	952 (buoy)
15	7045
25	7047 (Did not work)
40	7044
60	7052
82	310

TABLE 30. WHOI VLA external navigator

navigator	# 010 @ 28 meters depth
transponder depths	83 meters

TABLE 31. WHOI VLA navigator locations

transponder frequency	latitude (surveyed)	longitude (surveyed)
11.0 kHz	40 22.2948	71 13.5401 (1996)
12.0 kHz	40 21.9316	71 13.7797
11.5 kHz	40 22.2332	71 13.5882

TABLE 32. WHOI VLA hydrophone spacing

Depth (m)	phone number	status at end
20	0 (navigation phone)	intermittent
30	1	noisy
40	2 (navigation phone)	good
50	3	bad
60	4	intermittent
70	5	bad
80	6 (navigation phone)	intermittent
not used	7	break out
83	8 (7 m from anchor)	bad
83	9 (17 m from anchor)	bad
83	10 (27 m from anchor)	noisy
83	11 (37 m from anchor)	intermittent
83	12 (47 m from anchor)	good

TABLE 32. WHOI VLA hydrophone spacing

Depth (m)	phone number	status at end
83	13 (57 m from anchor)	bad
83	14 (67 m from anchor)	bad
83	15 (77 m from anchor)	bad

TABLE 33. Datafile status for VLA tape #00

date time	size (bytes)	# of recs
tape header	1024	1
02170157	16,793,600	16
02170236	6,297,600	6
02170529	192,076,600	183
02170642	6,297,600	6
02170646	314,880,000	300
02170843	263,449,600	251
02191606	314,880,000	300
02191803	314,880,000	300
02192001	314,880,000	300
02192158	81,068,800	78
02192356	314,880,000	300
02200026	314,880,000	300
02200224	314,880,000	300
02200421	314,880,000	300
02200619	314,880,000	300
02200816	314,880,000	300
02201014	314,880,000	300
02201211	251,904,000	240

TABLE 34. Datafile status for WVLA tape #01

date time	size (bytes)	# of recs
tape header	1 kb	1
02201345	314,880,000	300
02201543	314,880,000	300
02201740	314,880,000	300
02201938	314,880,000	300
02202135	314,880,000	300
02202333	314,880,000	300
02210130	251,904,000	240
02210304	210,969,600	201

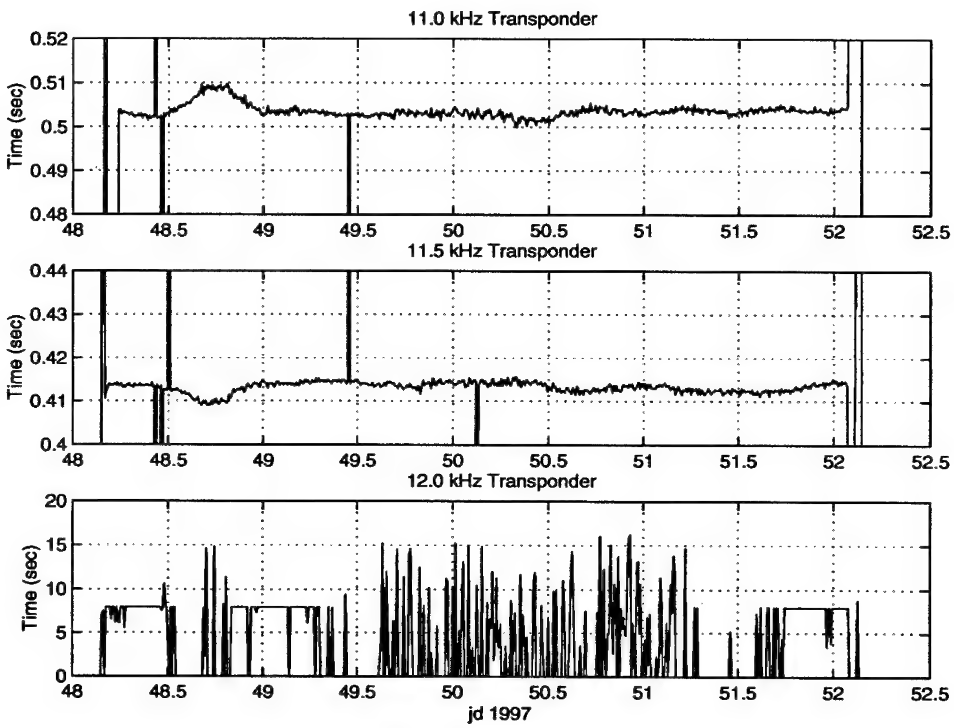


FIGURE 41. WHOI VLA navigator #10 travel times

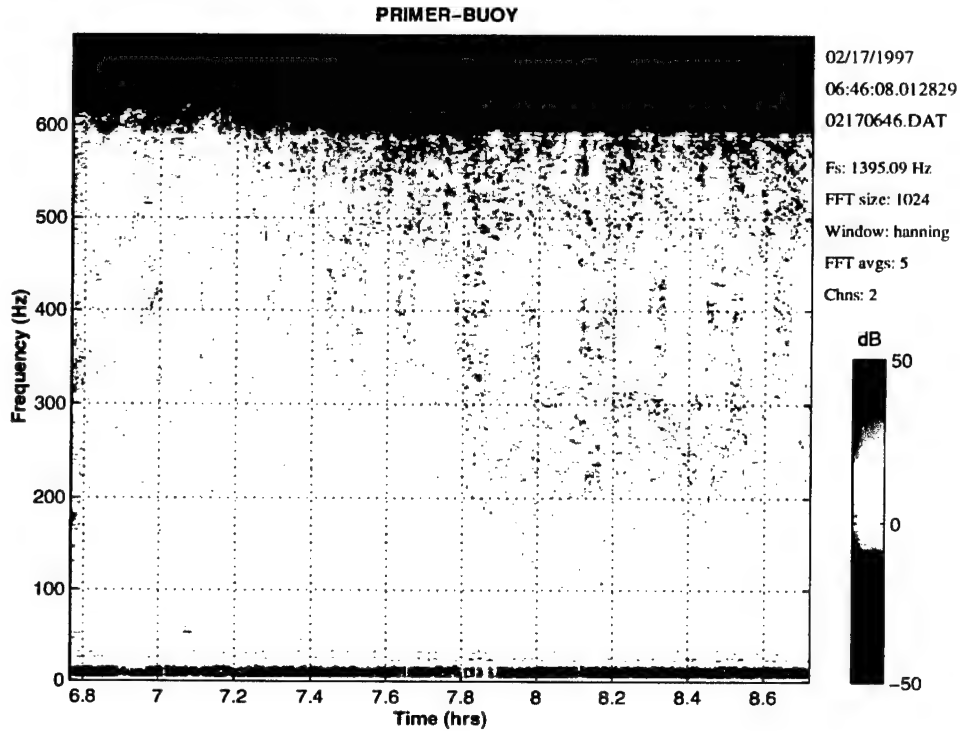


FIGURE 42. Frequency spectrum for all samples for start of experiment on 2/17 at 0646 from VLA

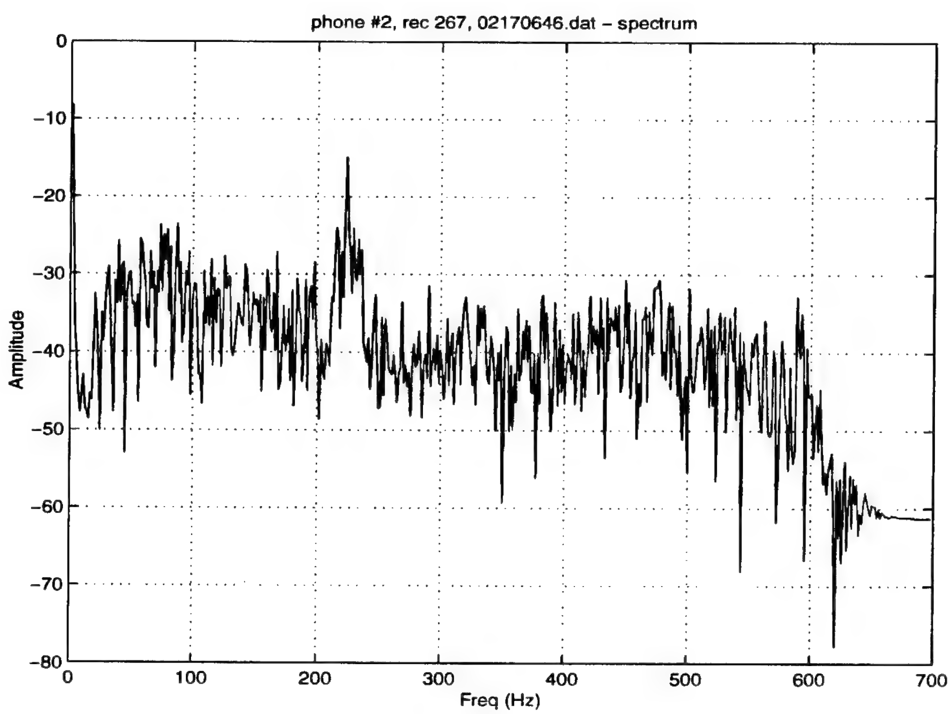


FIGURE 43. Frequency spectrum for phone #2 on 2/17 at 0646 showing 224 Hz signal from VLA

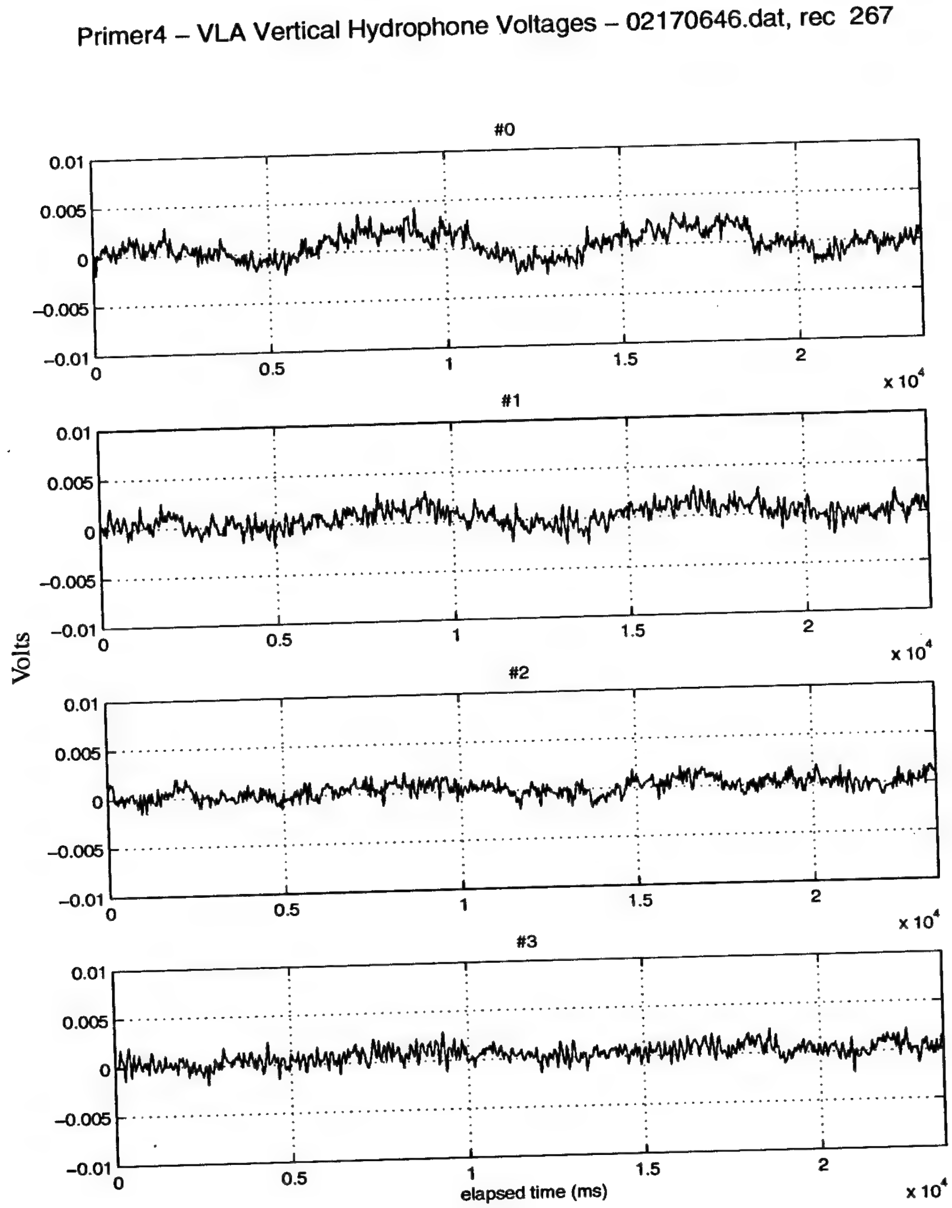


FIGURE 44. VLA vertical hydrophone voltages for phones 0-3, 2/17 at 0646, record number 267. Elapsed time is in milliseconds x10^4

Primer4 – VLA Vertical Hydrophone Voltages – 02170646.dat, rec 267

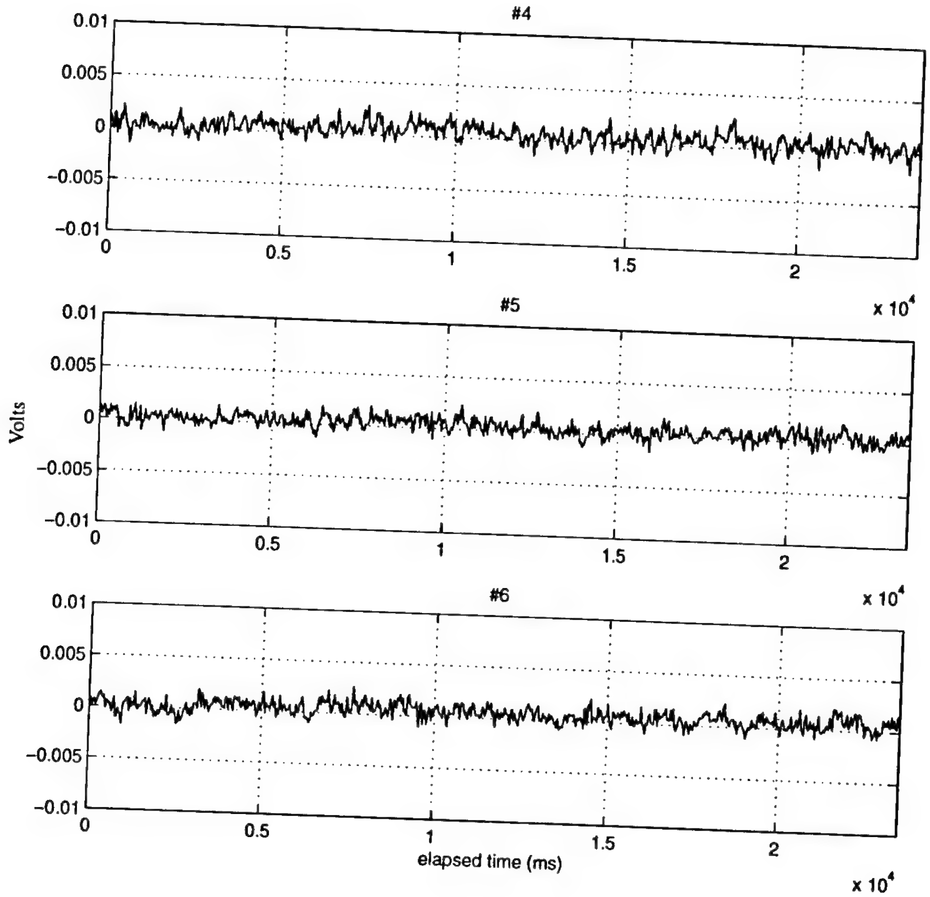


FIGURE 45. VLA vertical hydrophone voltages for phones 4-6, 2/17 at 0646, record number 267. Elapsed time is in milliseconds x10^4

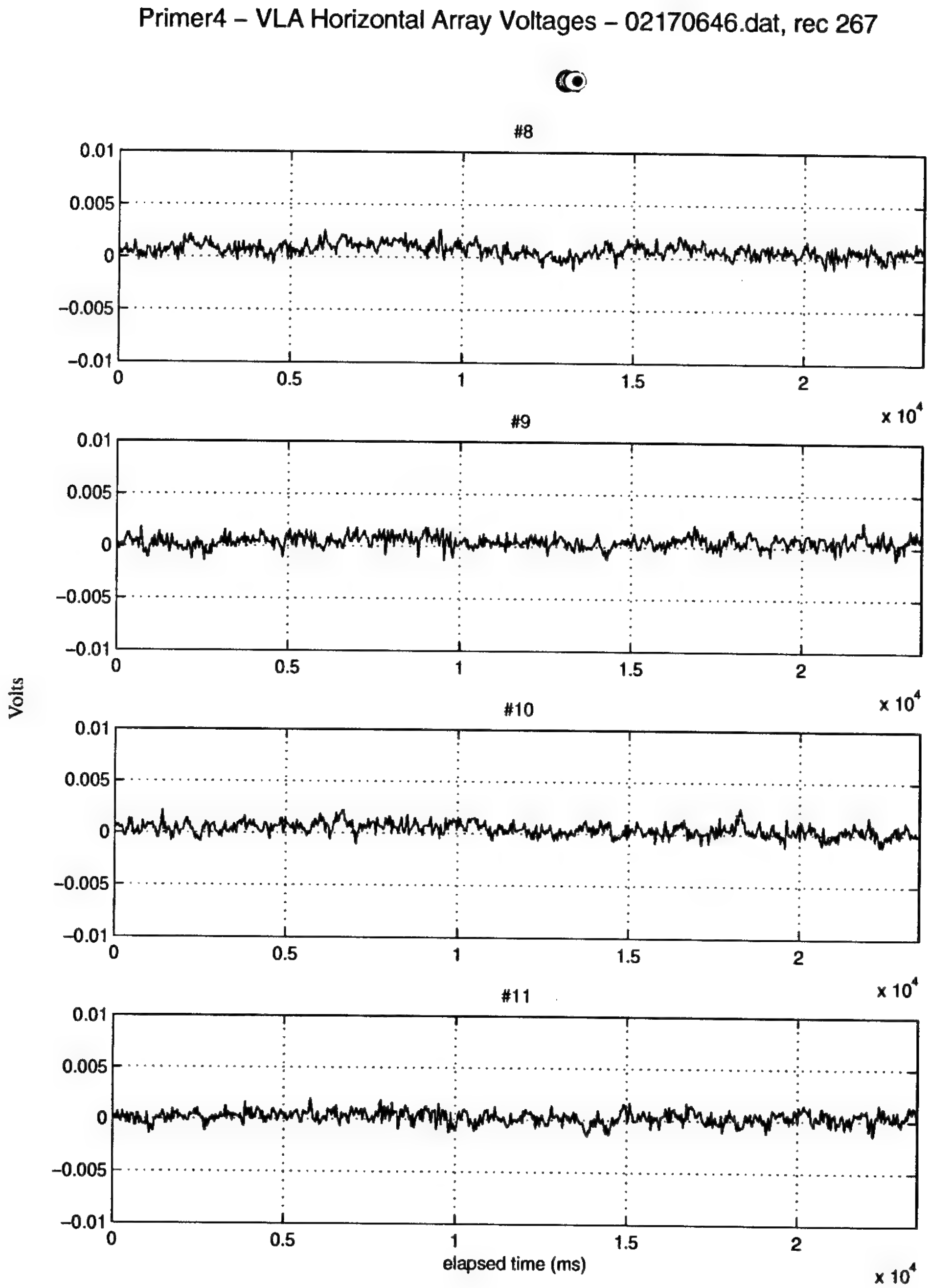


FIGURE 46. VLA horizontal hydrophone voltages for phones 8-11 on 2/17 at 0646, record 267. Elapsed time is in miliseconds x10^4.

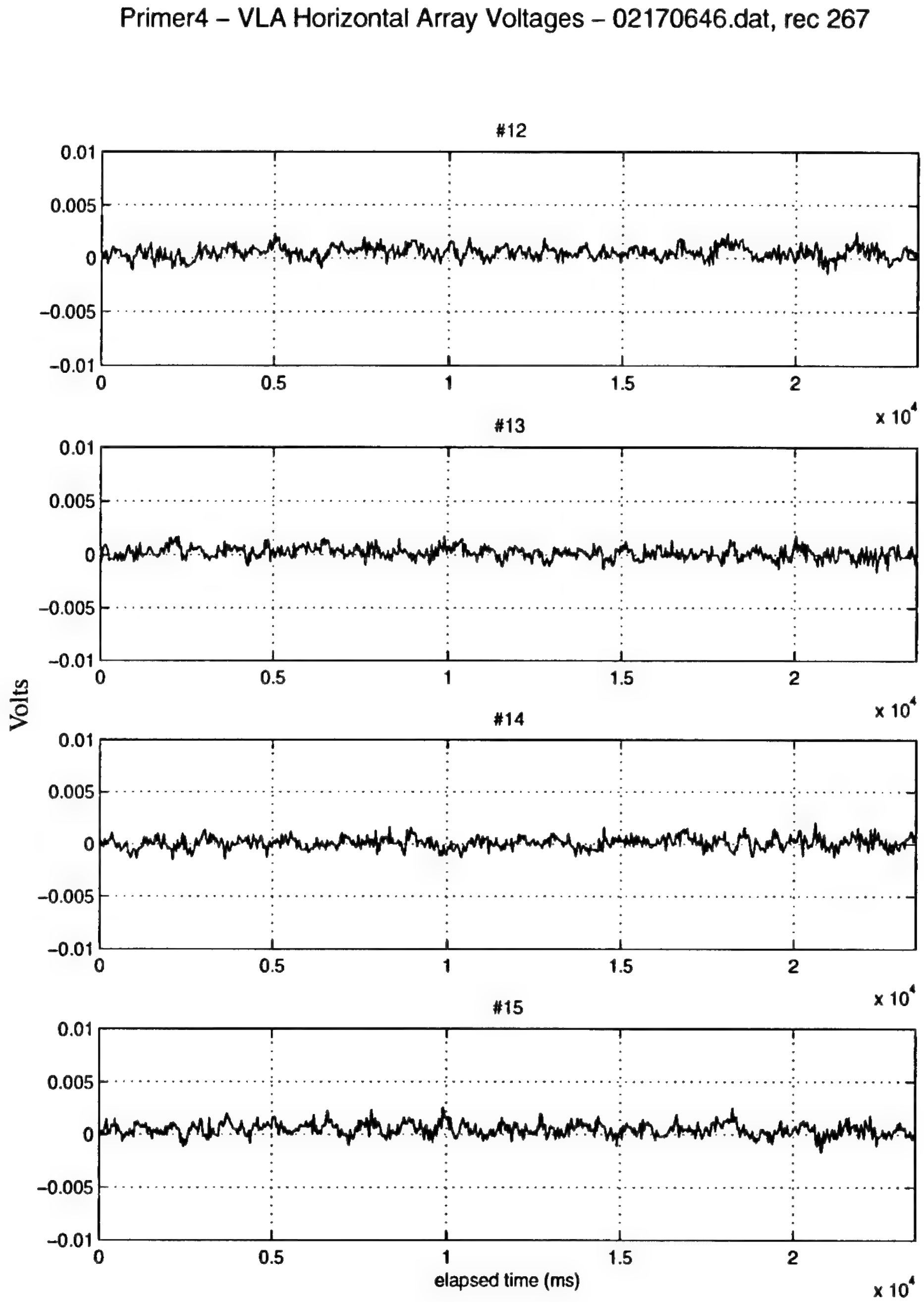


FIGURE 47. VLA horizontal hydrophone voltages for phones 12-15 on 2/17 at 0646, record 267. Elapsed time is in miliseconds x10^4.

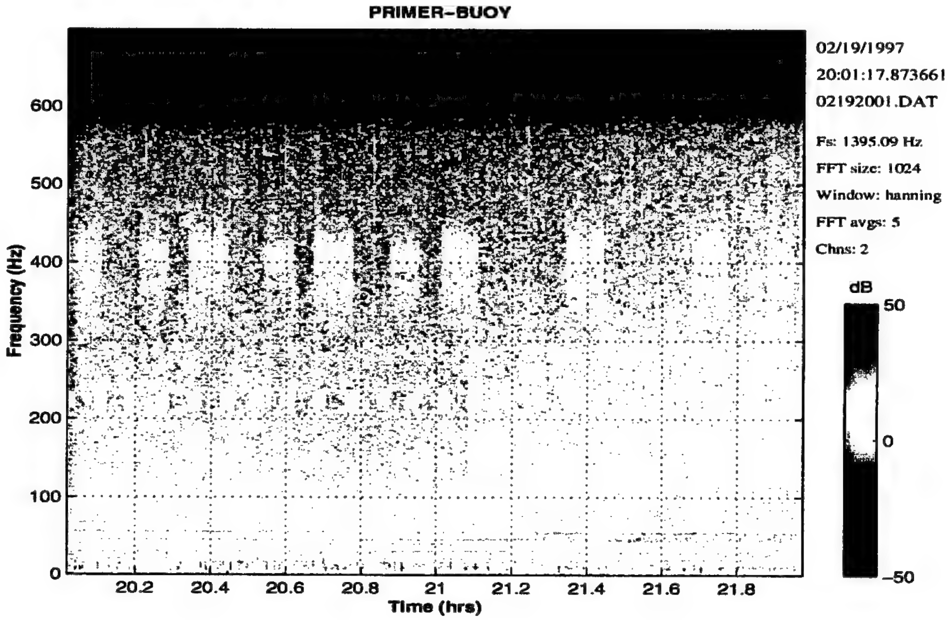


FIGURE 48. VLA channel #2 frequencies for 02/19 at 2001.

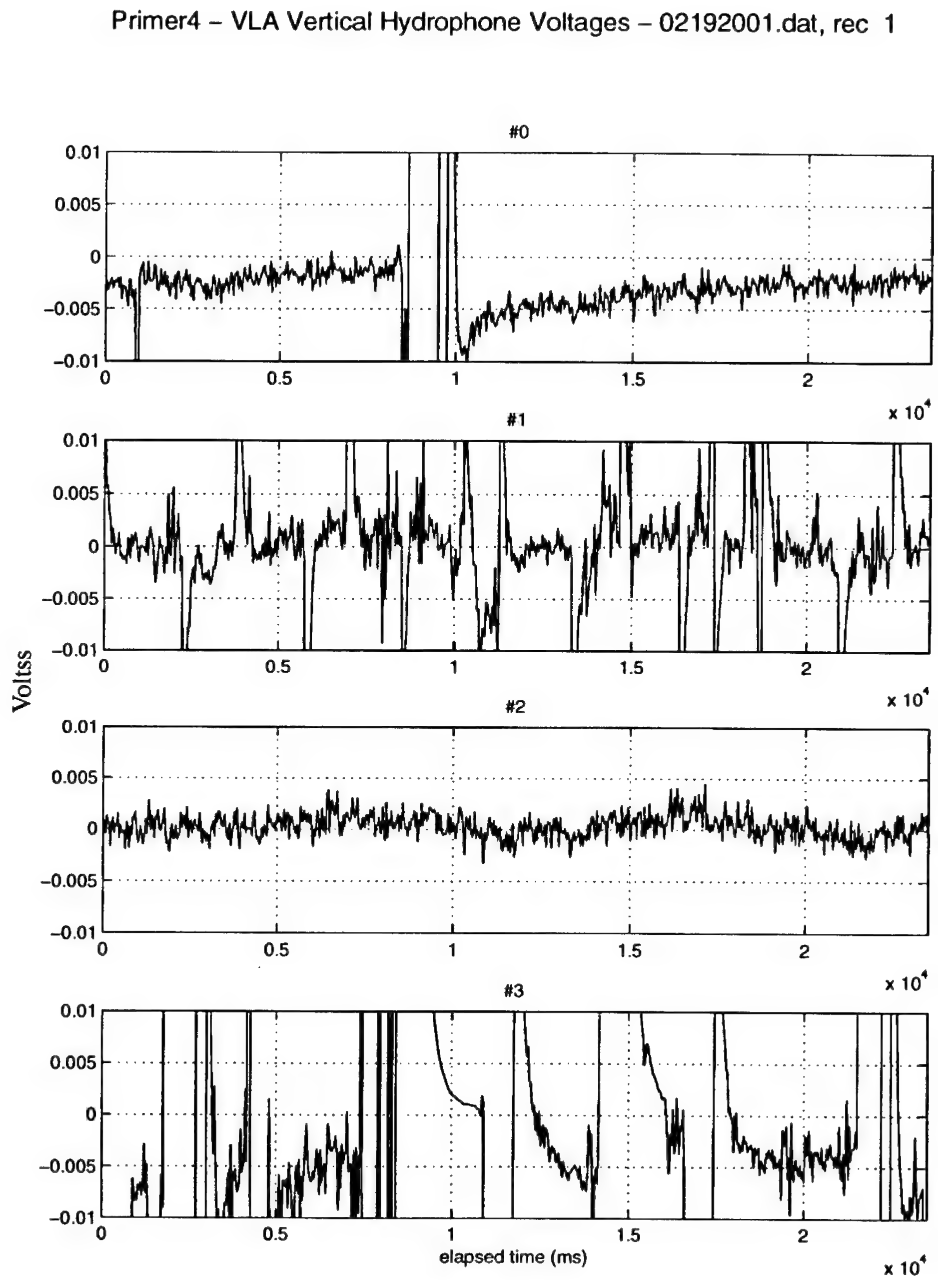


FIGURE 49. VLA vertical hydrophone voltages for phones 0-3 two days into experiment now showing problems. Only hydrophone #2 is unaffected. Elapsed time is in milliseconds $x10^4$.

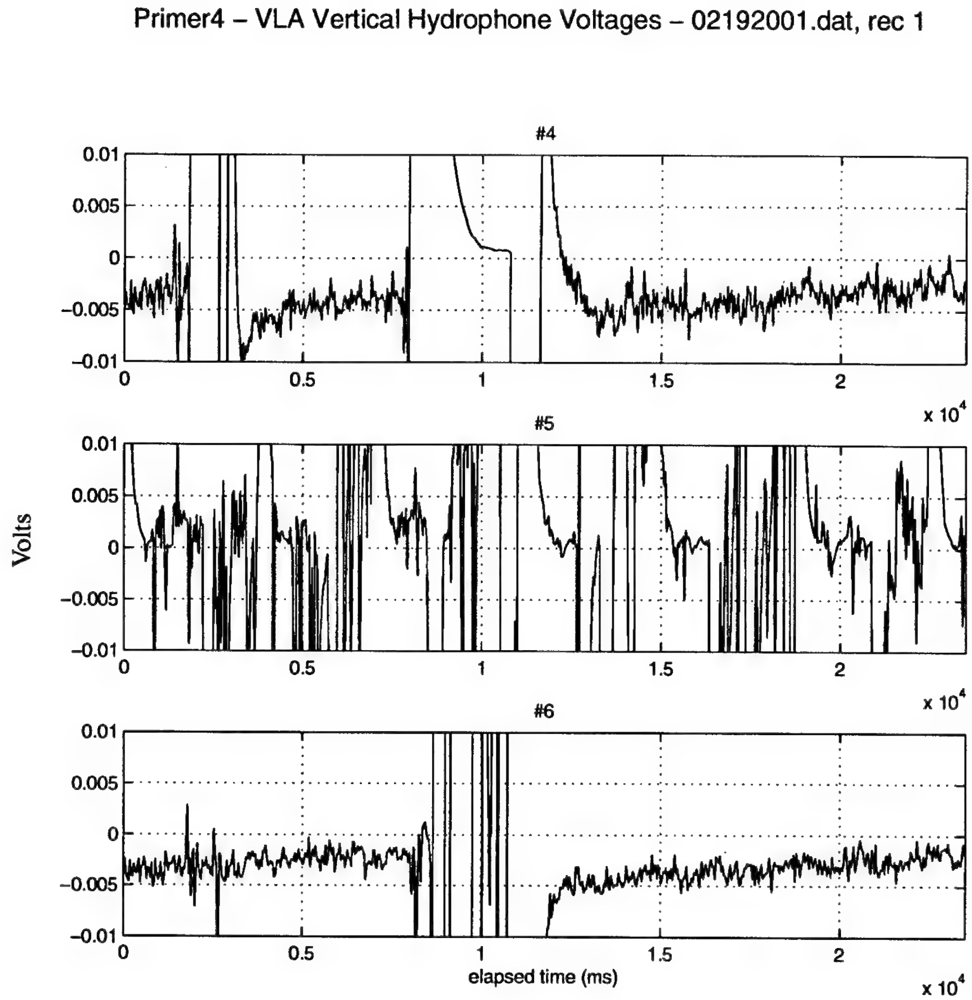


FIGURE 50. VLA vertical array hydrophones 4-6 two days into experiment now showing problems. Elapsed time is in milliseconds x10^4.

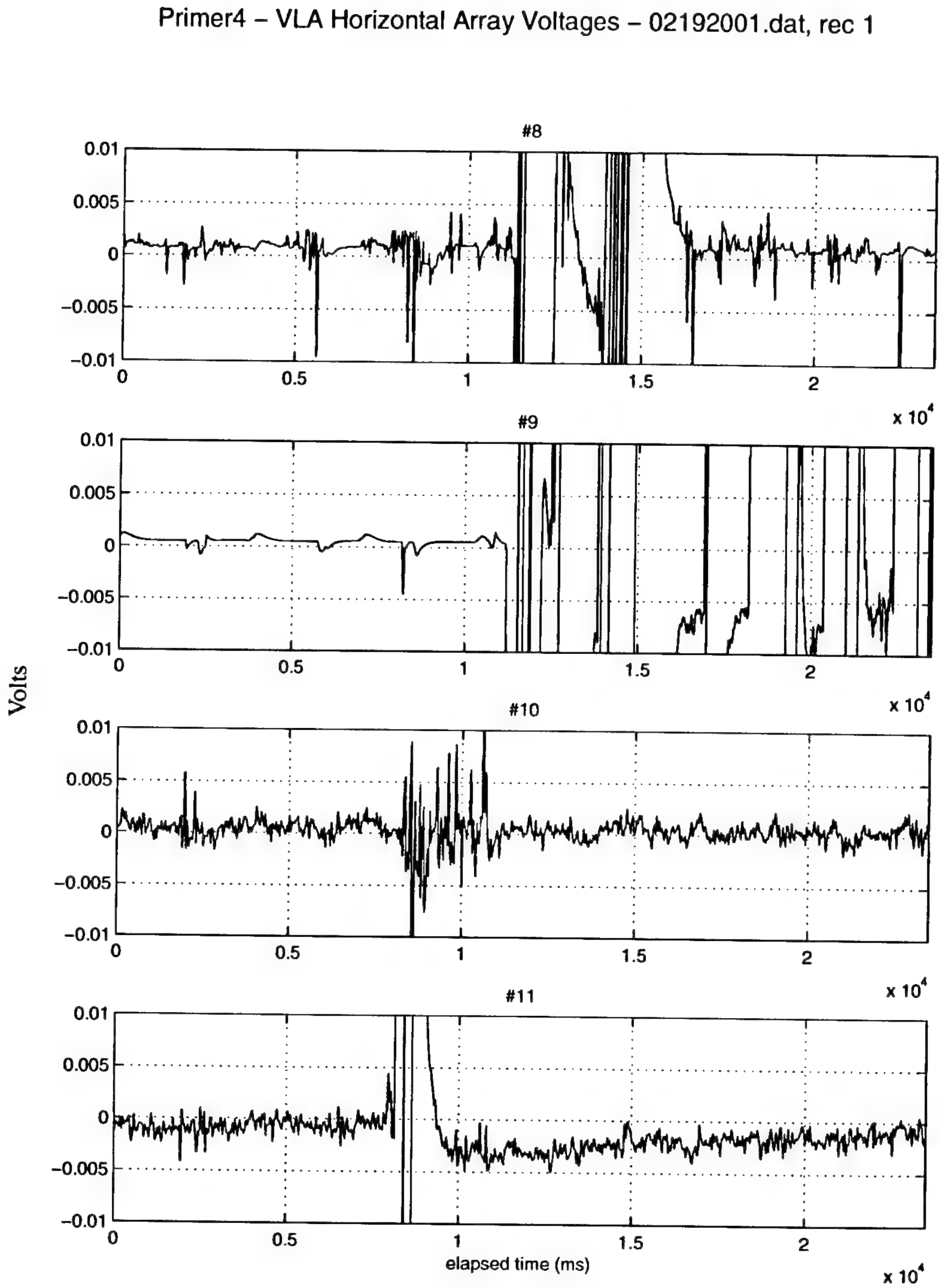


FIGURE 51. VLA horizontal array hydrophones 8-11 two days into experiment now showing problems. Elapsed time is in milliseconds x10^4.

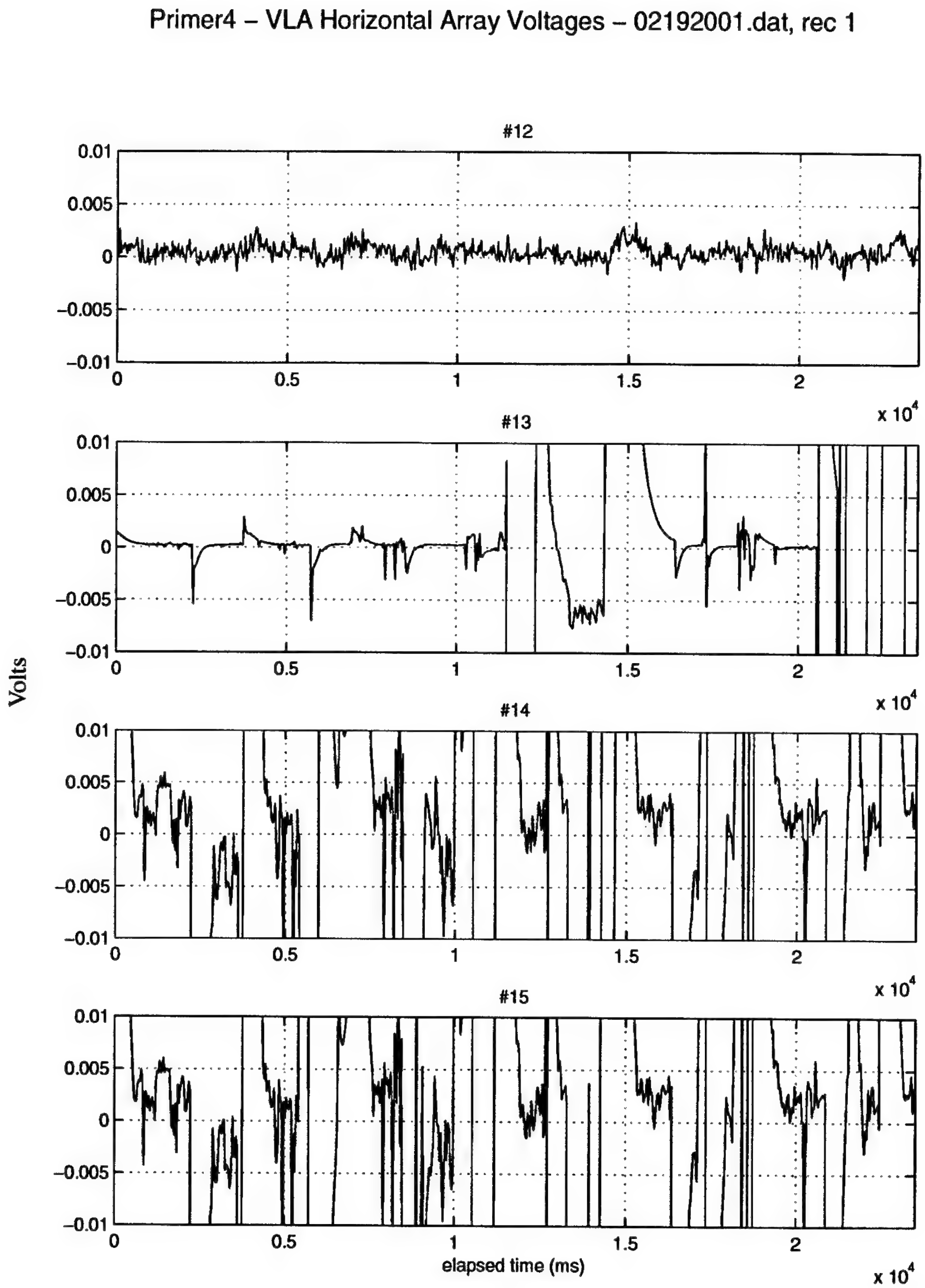


FIGURE 52. VLA horizontal array hydrophones 12-15 two days into experiment now showing problems. Only hydrophone #12 is unaffected. Elapsed time is in milliseconds x10^4.

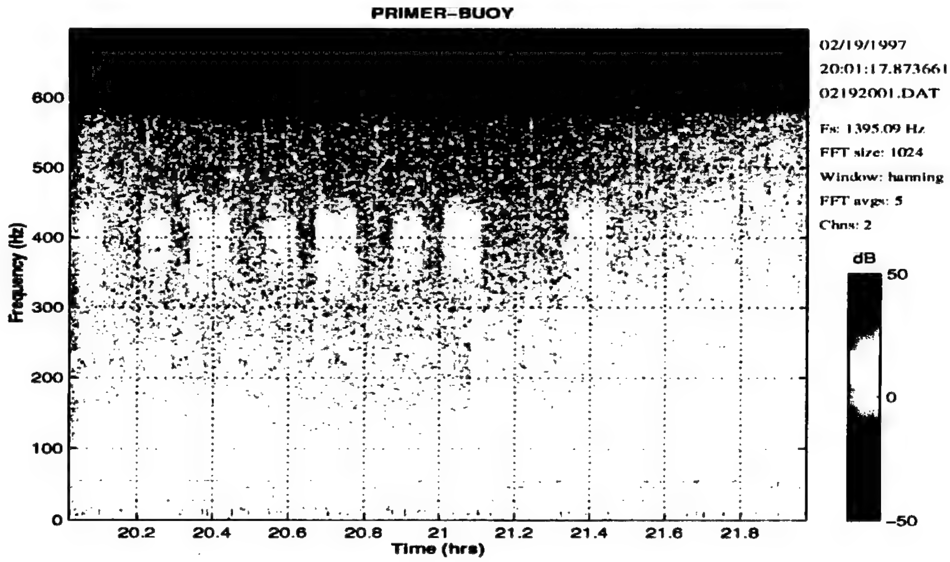


FIGURE 53. VLA frequency spectrum for channel #2 at end of experiment.

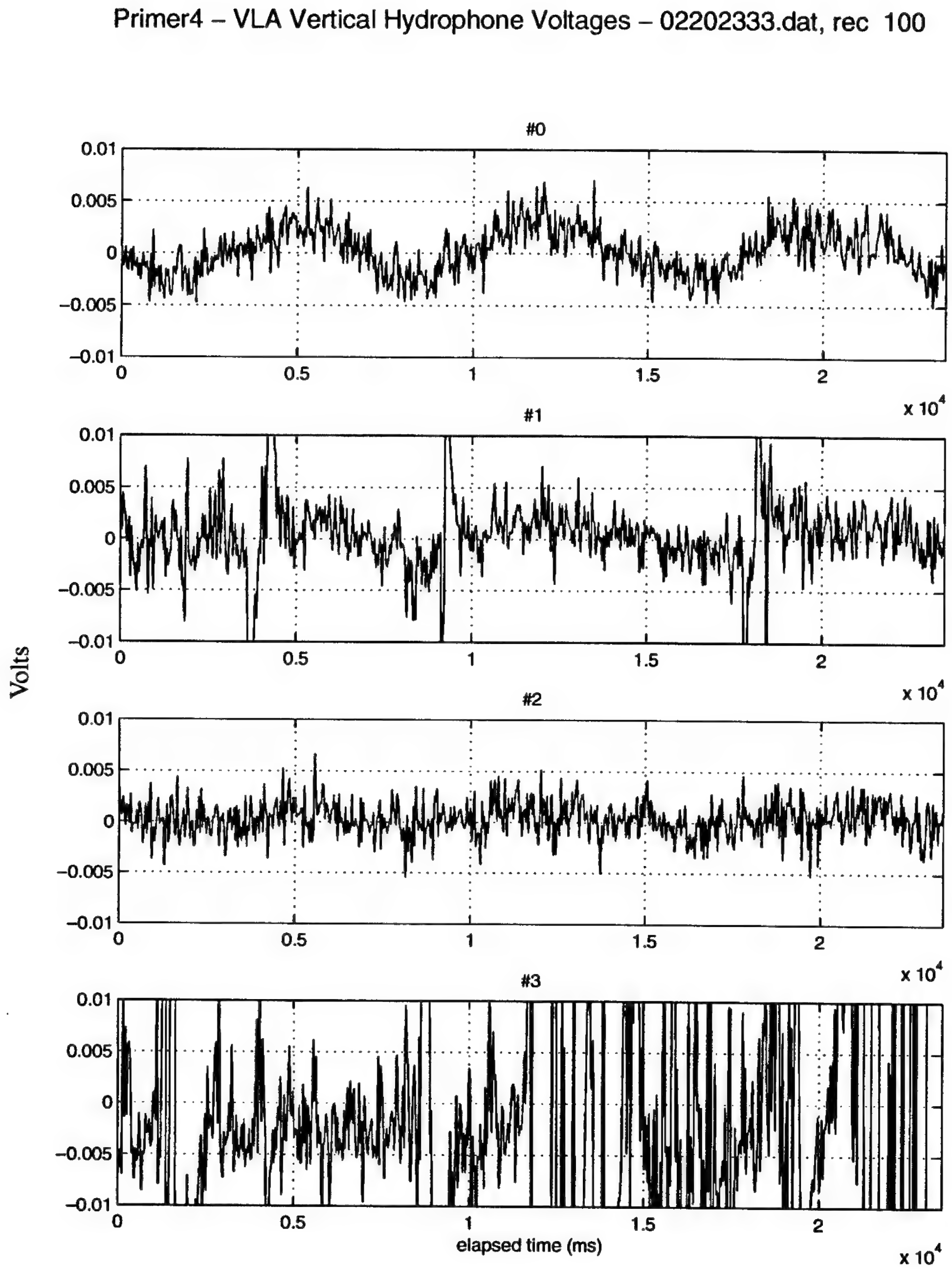


FIGURE 54. VLA vertical array voltages for phones 0-3 at end of experiment. Elapsed time is in milliseconds x10^4.

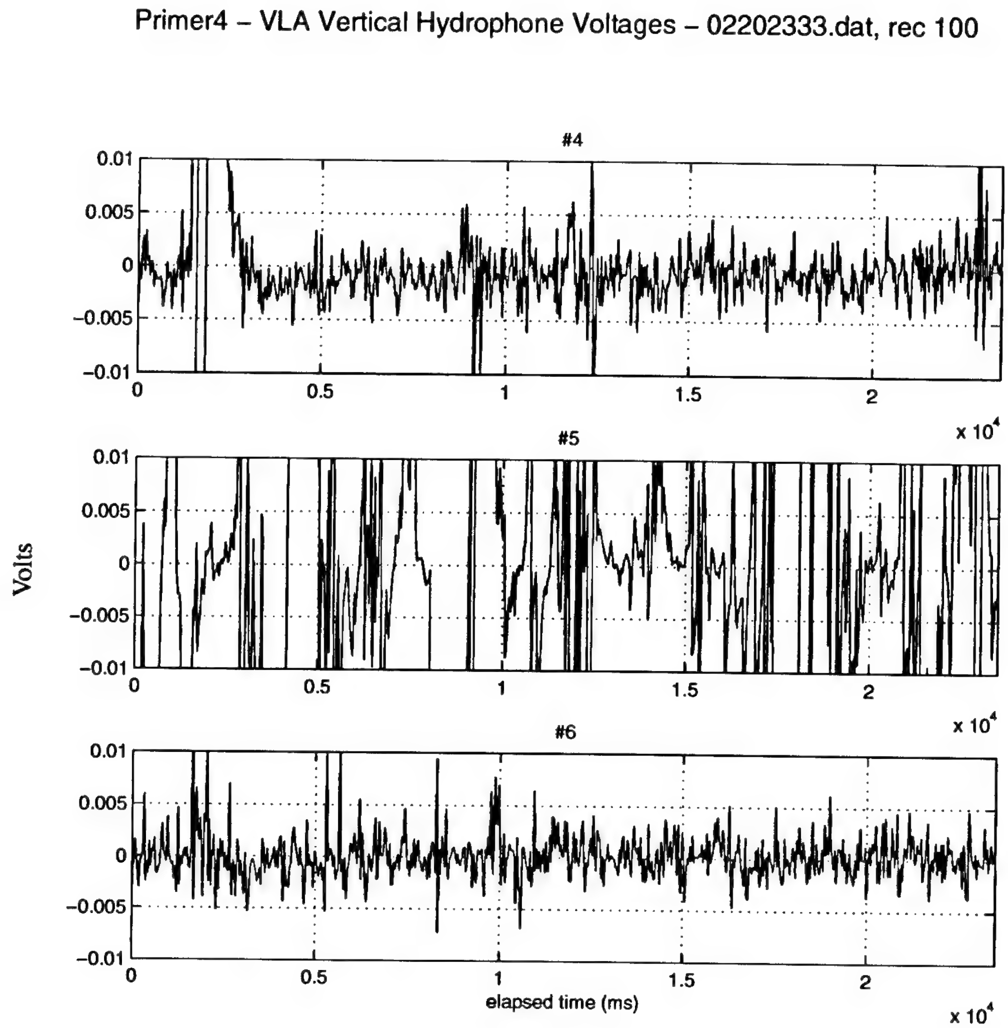


FIGURE 55. VLA vertical array voltages for phones 4-6 at end of experiment. Elapsed time is in milliseconds x10^4.

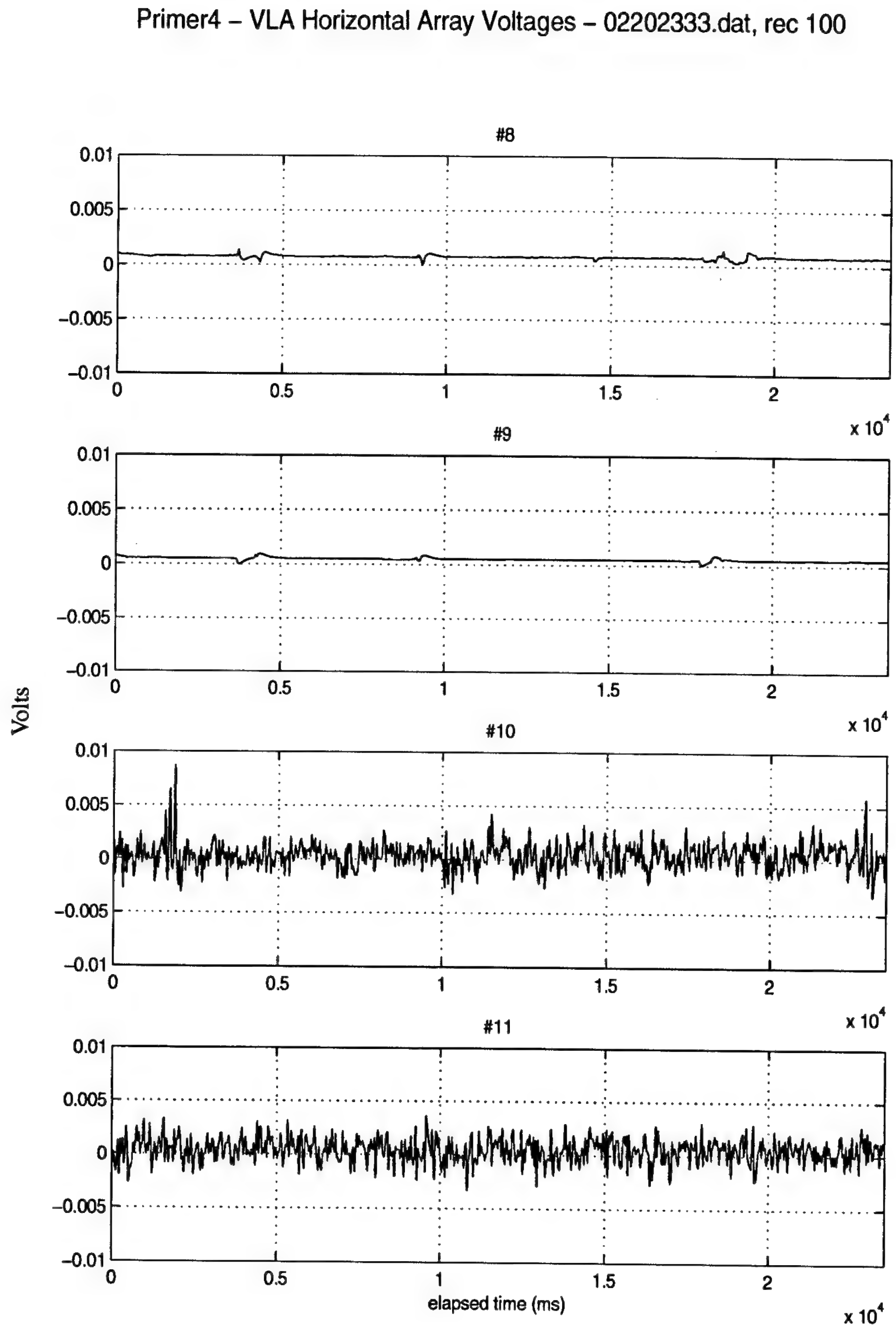


FIGURE 56. VLA horizontal array voltages for phones 8-11 at end of experiment. Elapsed time is in milliseconds x10^4.

Primer4 – VLA Horizontal Array Voltages – 02202333.dat, rec 100

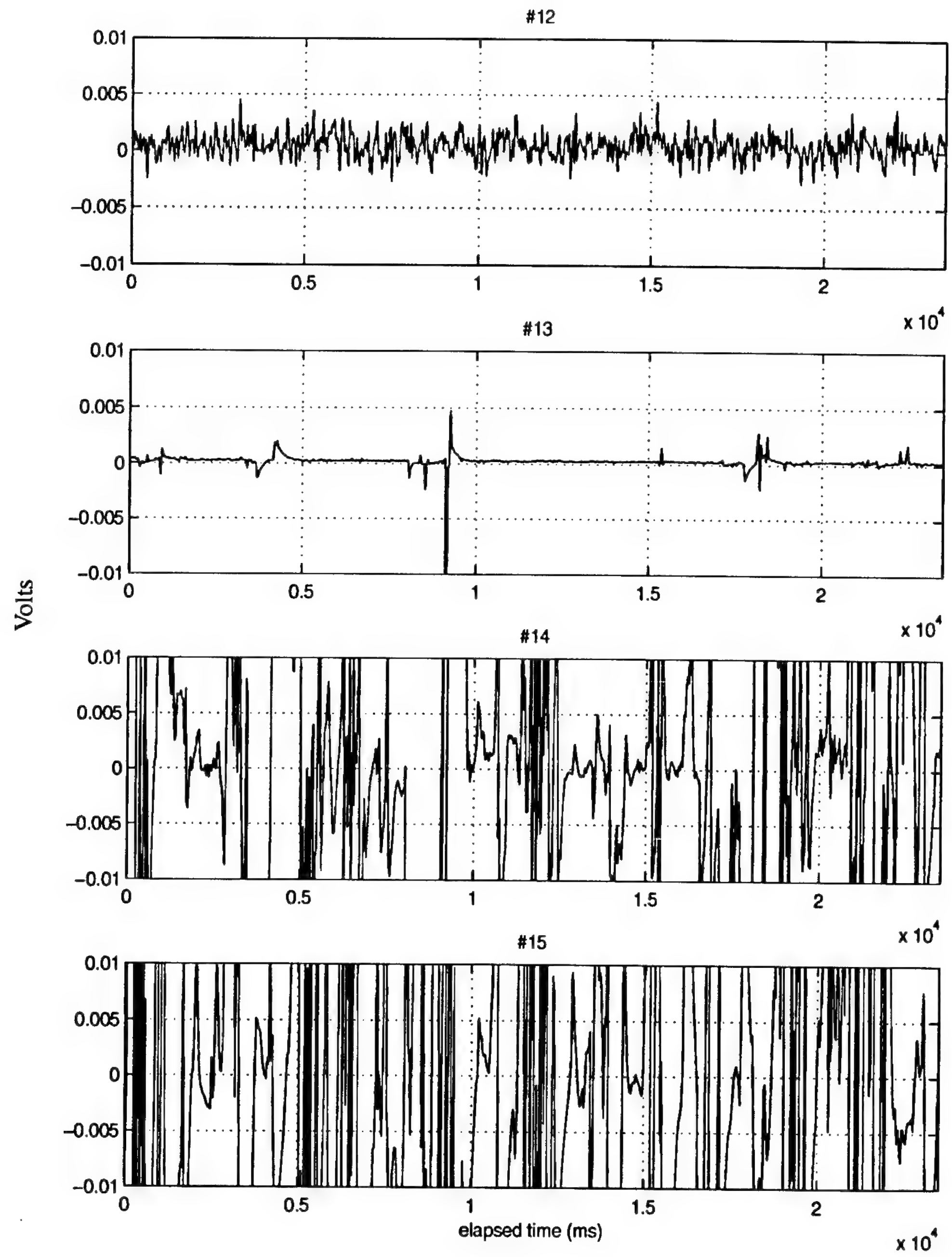


FIGURE 57. VLA horizontal array voltages for phones 12-15 at end of experiment. Elapsed time is in milliseconds x10^4.

2.7.2 "Shark of Science" vertical array

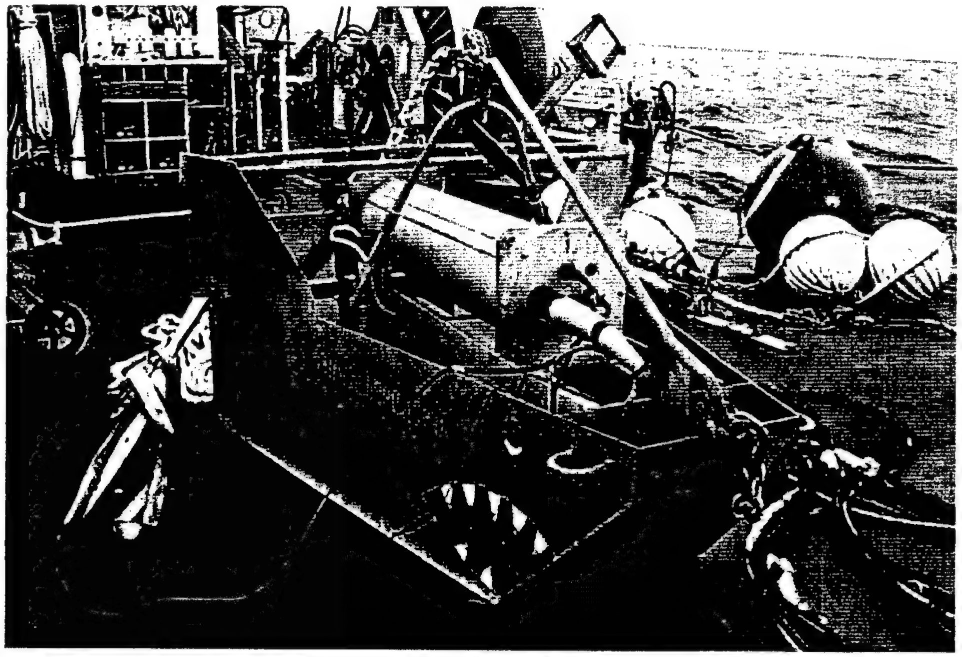


FIGURE 58. The "Shark of Science" anchor containing storage electronics.

The "Shark of Science" hydrophone array got its name from the shape of the array anchor/ instrument sled. The mooring is U-shaped and contains two anchors 180 meters apart. One anchor was designed to hold the array electronics housing and also to be a vehicle which can "fly" through the water until it finds a suitable anchoring location (fig 58). The welder who assembled the vehicle thought it looked like a shark so he welded eyes and a sharp-toothed mouth onto the vehicle; thus "Shark of Science".

All hydrophones on the Shark worked throughout the experiement. Shark was started on Feb 11 at 1600 hours. Datafile #1 contains pre-deployment test data that were taken on deck. The Shark anchor did not have an acoustic release, so the actual mooring location was not surveyed.

Note: Shark datafile header dates have wrong year, should be 1997, not 1996!

The signal to noise ratio was very good for all receptions by the Shark from the beginning of the experiment (fig 59) to the end (fig 61). The missing 400 Hz signal at 6 minutes after the hour from the Central source is evident in the data (fig 60). All phones also were recording at the end (fig 62,63,64,65).

The format of the internal VLA navigation data is a sequence of groups of 22 ASCII numbers. Each group represents the 2-way travel time measured from the WHOI pinger mounted on the sled, to each of the 3 Benthos transponders, and back to selected hydro-

phones on the vertical array. The data in each group establish the date, time, and travel time.

The ping duration from the WHOI pinger was 10 ms. The pinger fired 4 times at 5 second intervals starting at precisely the reported time. The intended timing of navigation "epochs" was every 5 minutes starting at 2 minutes after the hour. The sequence of events were:

- at the beginning of epoch, a pre-selected channel was applied to the detectors and the pinger was fired.
- the time of the first detection at each of 4 frequencies (3 transponder reply frequencies and the pinger frequency of 10.5 kHz) was noted until a 5 second window had elapsed.

No corrections have been made to accommodate detection latency or "turnaround" times in the Benthos transponders. The detectors in the VLAs have a detection delay of about 3 ms. The reported round trip traveltimes are in microseconds.

The numbers reported per navigation epoch are:
month day hour minute second microseconds

(10.5 to channelA) (11.0 to channelA) (11.5 to channelA) (12.0 to channelA)
(10.5 to channelB) (11.0 to channelB) (11.5 to channelB) (12.0 to channelB)

The internal navigation for both channels 0 and 6 show multipath jumps (figs 66, 67) most likely due to the foot of the front interacting with the paths. The external navigator was much higher on the mooring and doesn't show the multipath effects (fig 68). One of the channels of the external navigator failed to work properly, but only two travel time arrivals are sufficient for performing localization. In previous shallow water experiements, localization was more sensitive to the water temperature than the 2-way travel time so the navigation data was not used for localization in these cases. Fortunately, the moorings are rigid enough to prevent large off-center excursions.

TABLE 35. "Shark of Science" VLA

deployed	2/11/97 1800 (Z)
recovered	2/20/97 2320 (Z)
latitude N	40 22.599 (deployed)
longitude W	70 40.189 (deployed)
water depth	87.6 meters

TABLE 36. Shark VLA hydrophone spacing

Depth (m)	phone number
35.7	0
37.9	1
41.2	2
44.5	3
47.8	4
51.1	5
54.4	6
57.7	7
61.0	8
64.3	9
67.6	10
70.9	11
74.2	12
77.5	13
80.8	14
84.1	15

TABLE 37. Shark VLA external navigator

navigator	#009 @ 33.5 meters
transponder depths	87.6 meters

TABLE 38. Shark navigator locations

Transponder frequency	latitude (surveyed)	longitude (surveyed)
11.0 kHz	40 22.3496	70 39.8827
11.5 kHz	40 22.7977	70 40.1860
12.0 kHz	40 22.3935	70 40.4087

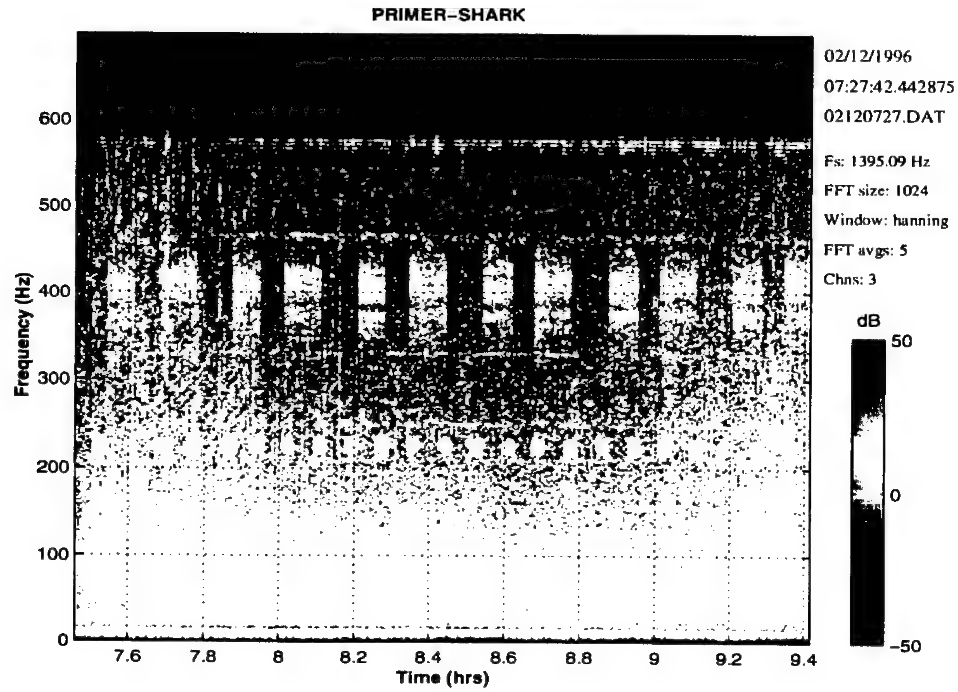


FIGURE 59. Frequency receptions for the Shark just after deployment.

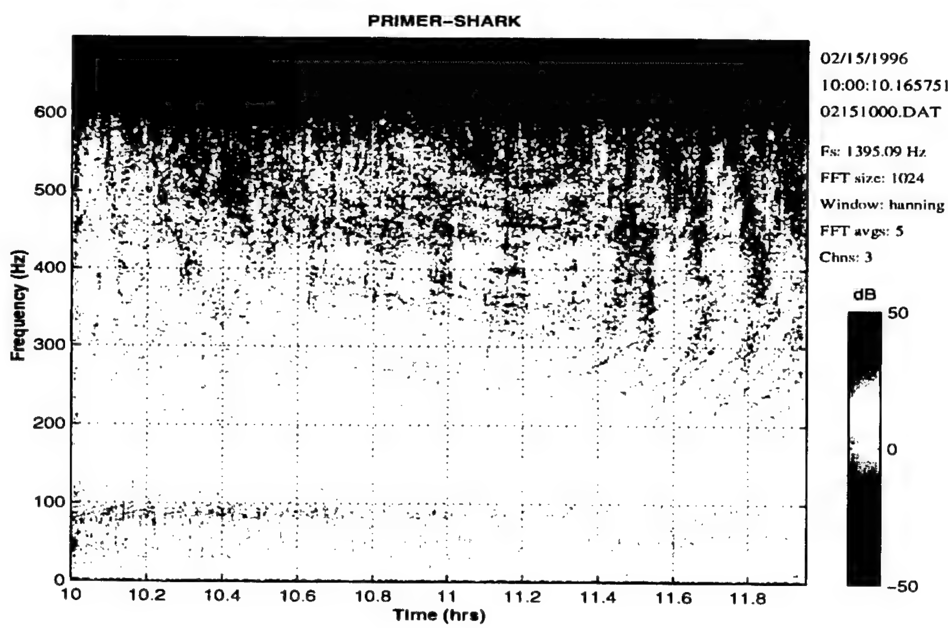


FIGURE 60. Frequency receptions for the Shark just before recovery. The circular patterns are ship noise frequencies.

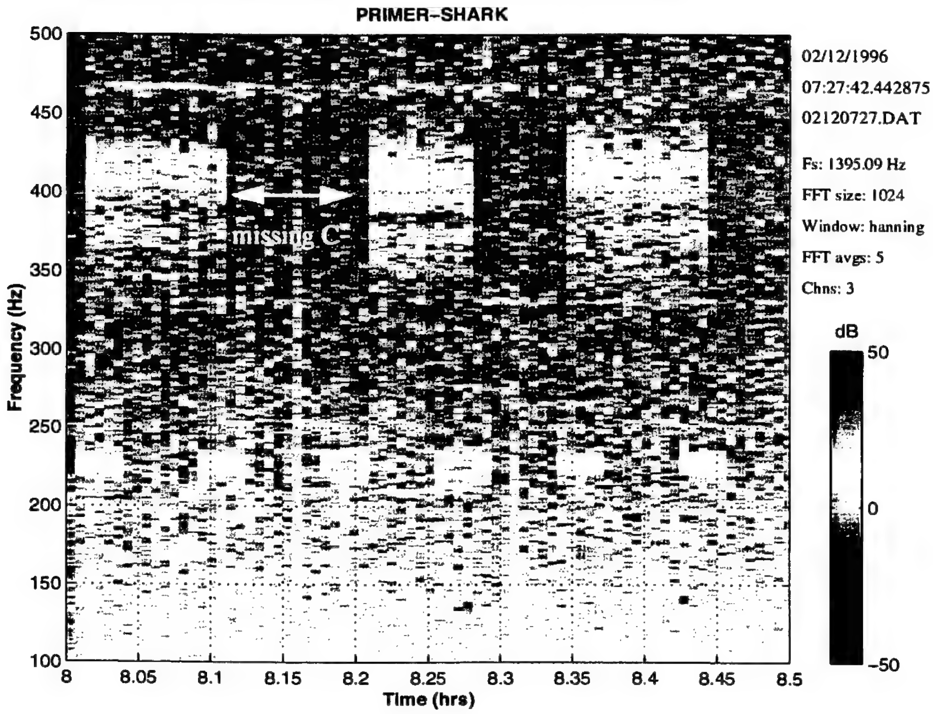


FIGURE 61. Zoomed in portion of Shark receptions just after deployment showing missing mooring C signals.

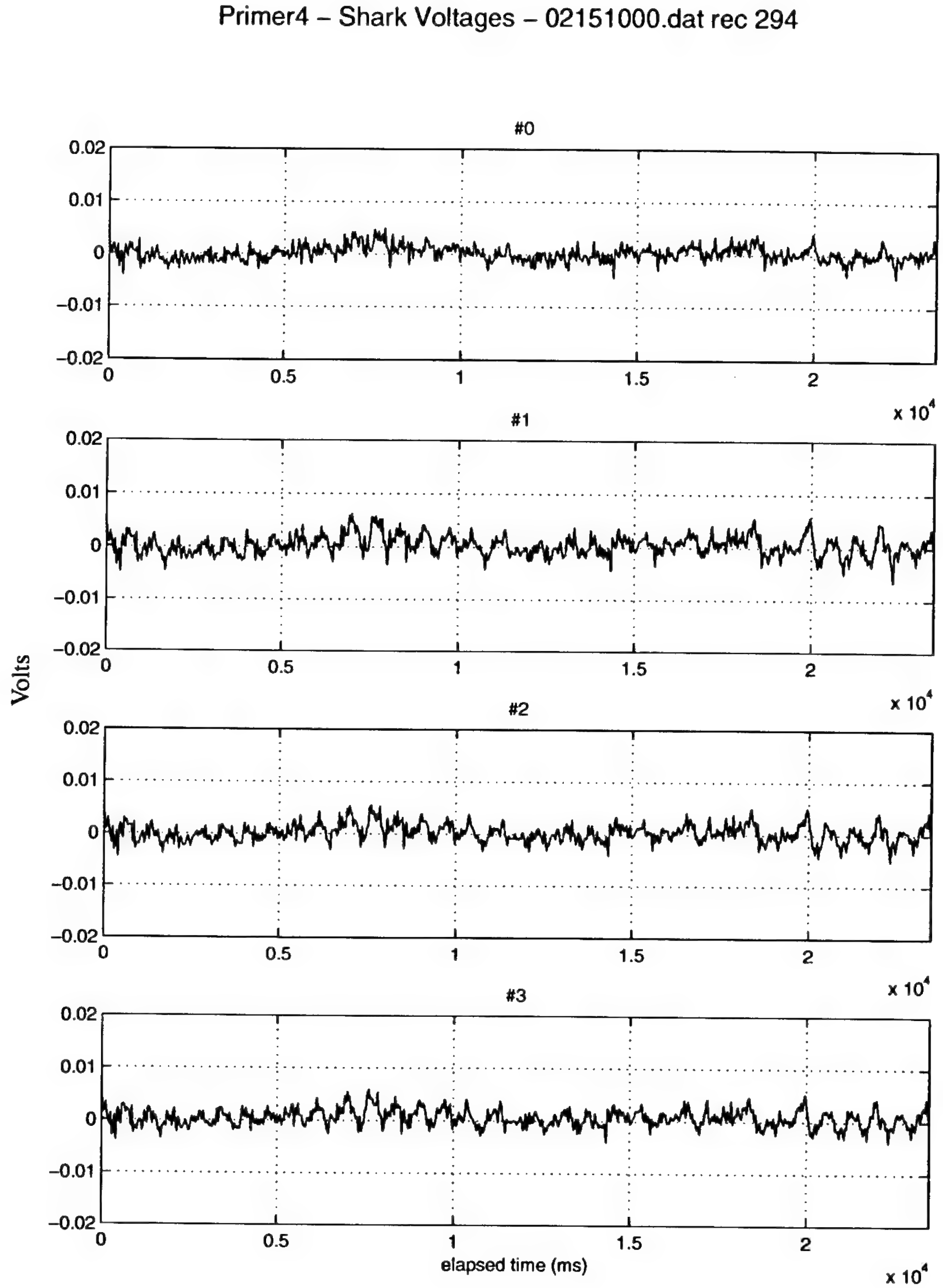


FIGURE 62. Shark individual phones #0-3 at recovery. Elapsed time is in milliseconds x10^4.

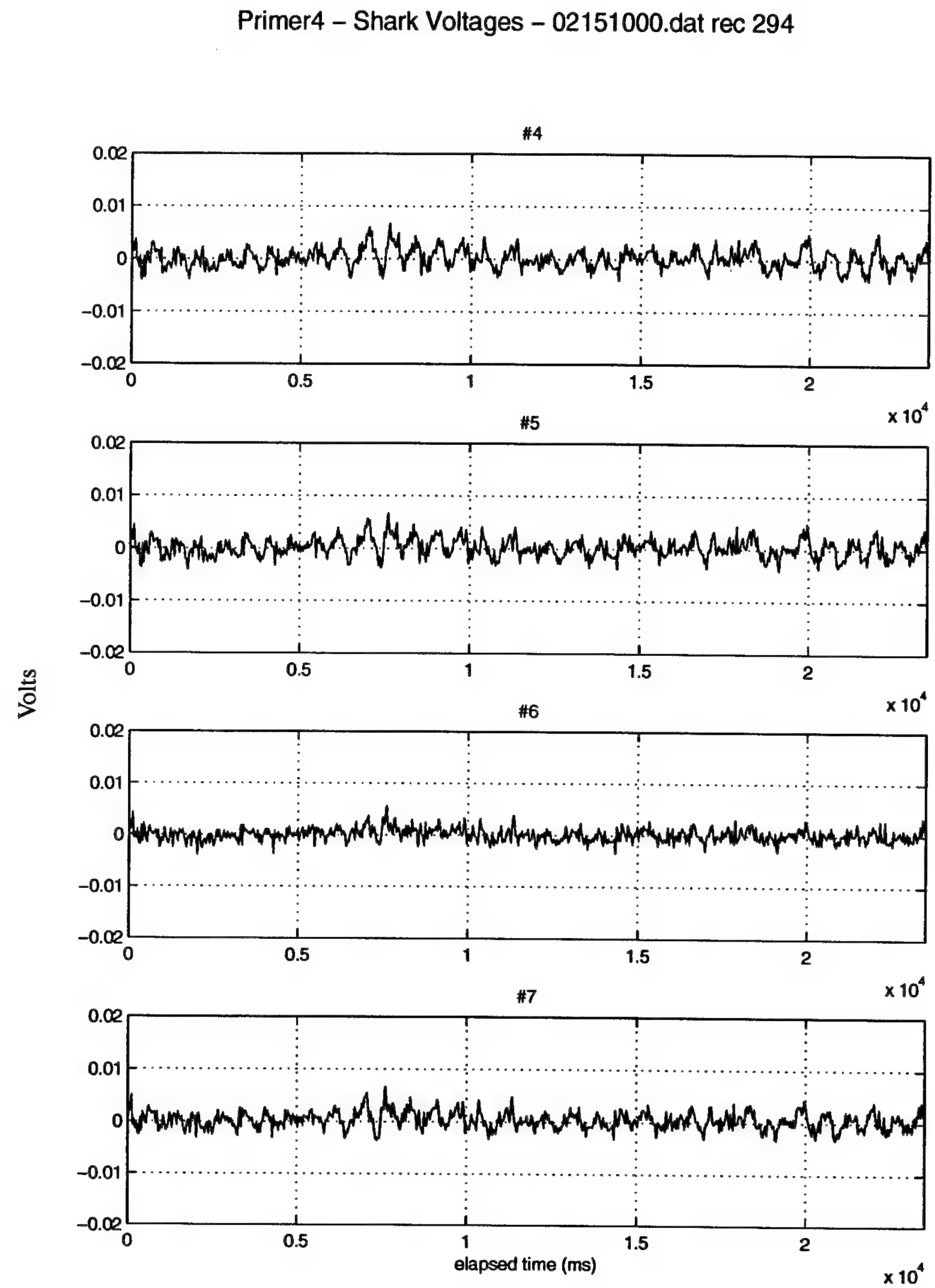


FIGURE 63. Shark voltages for phones #4-7 at recovery. Elapsed time is in milliseconds x10^4.

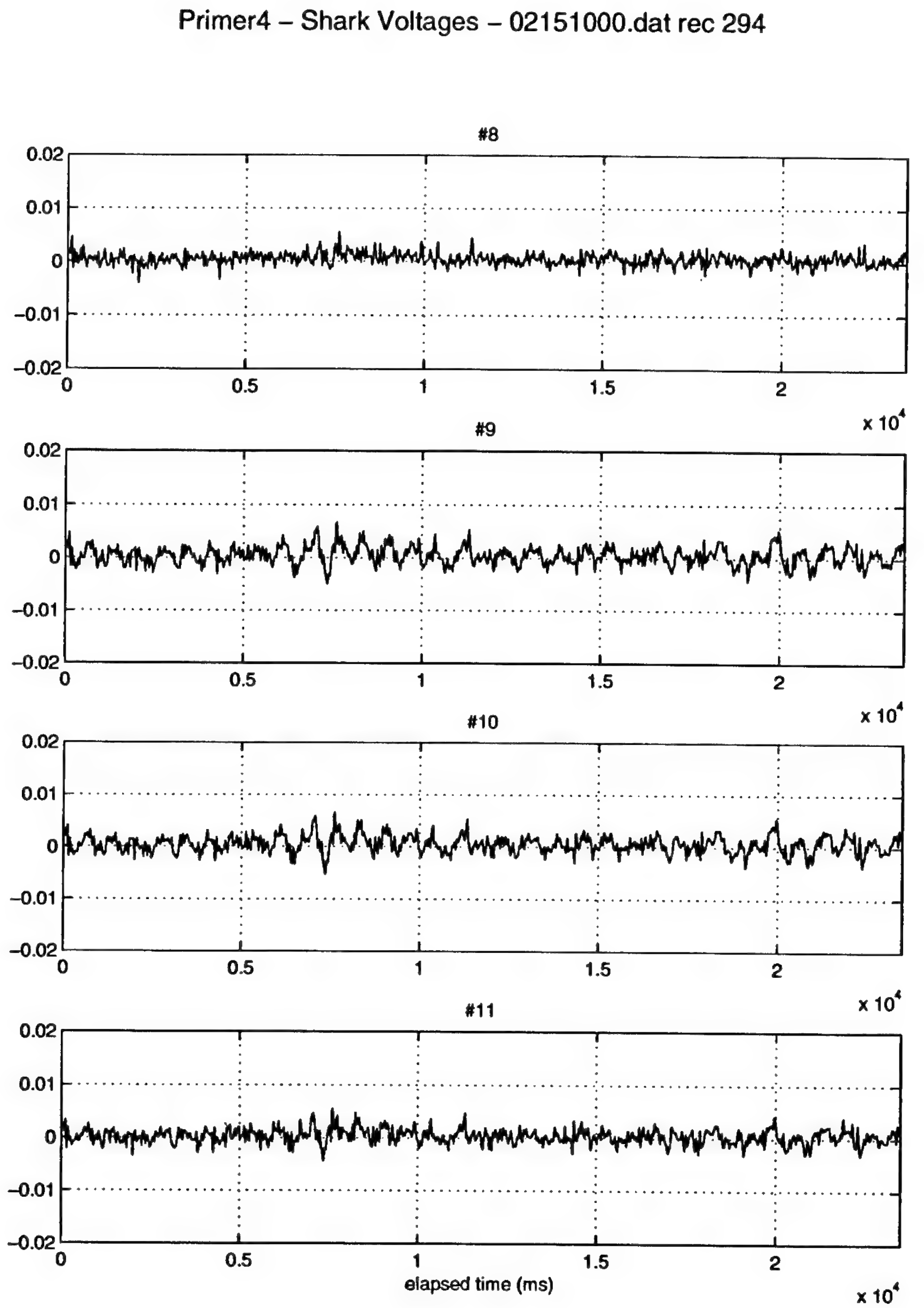


FIGURE 64. Shark voltages for phones #8-11 at recovery. Elapsed time is in milliseconds $x10^4$.

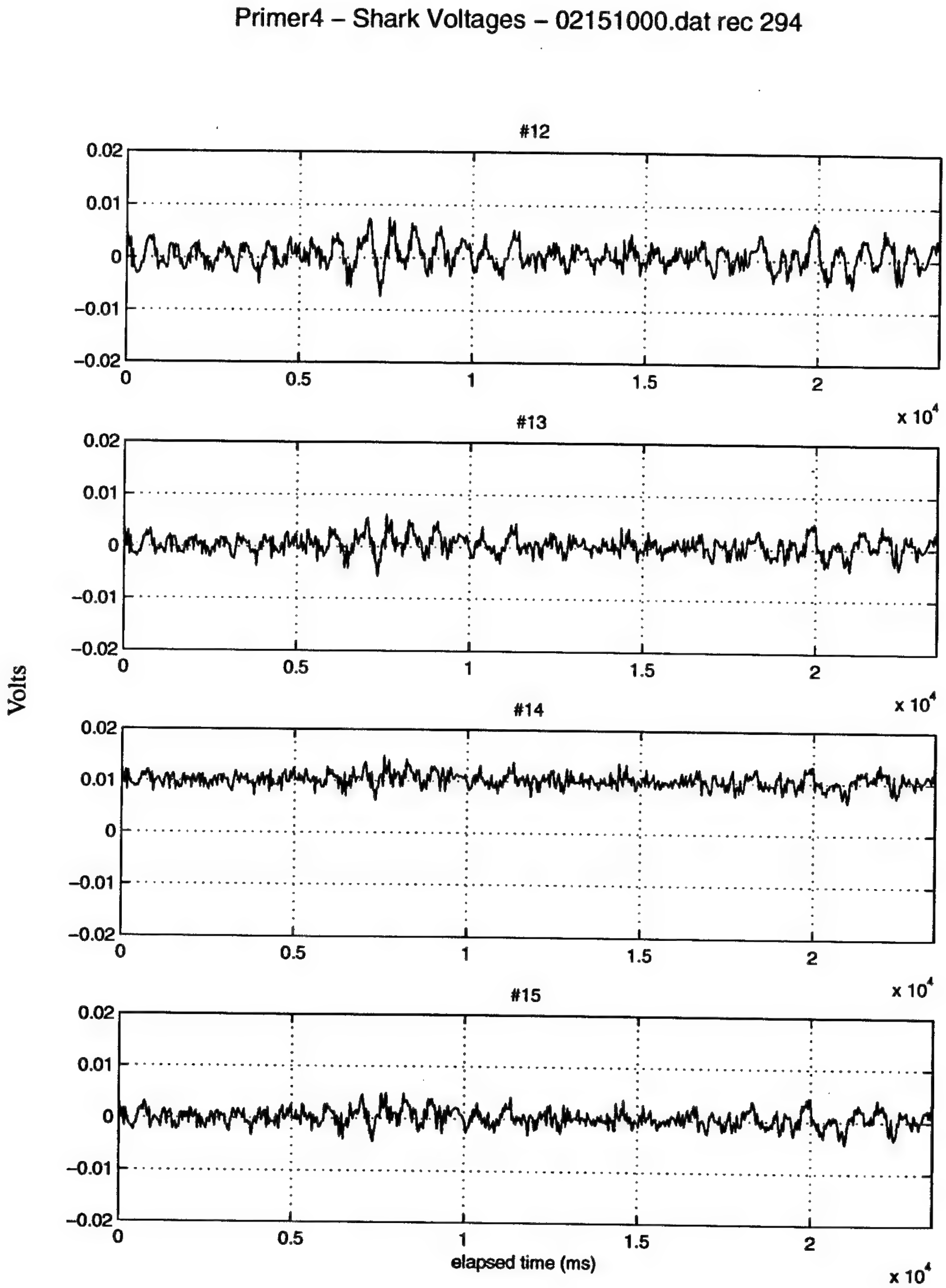


FIGURE 65. Shark individual phones #12-15 at recovery. Elapsed time is in milliseconds x10^4.

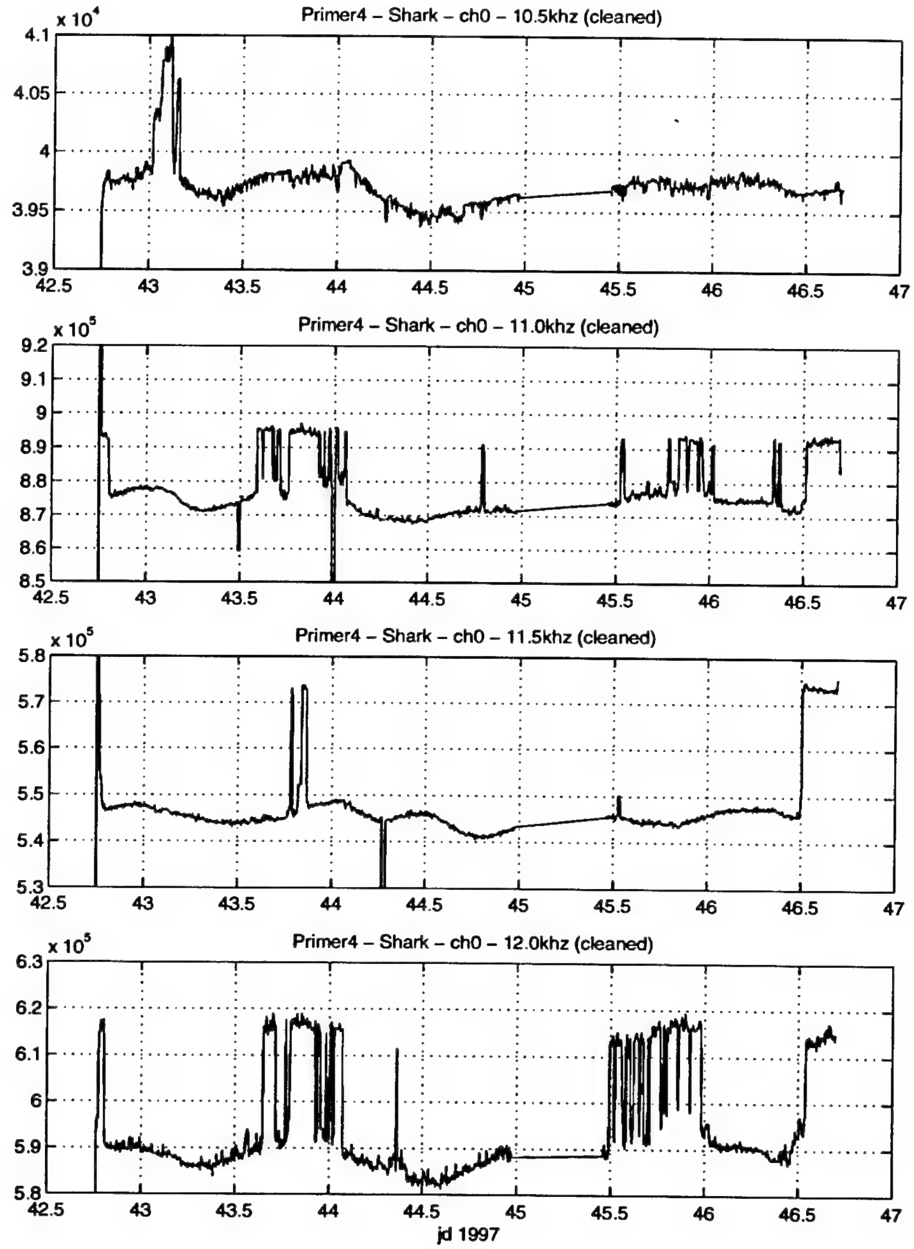


FIGURE 66. Shark internal navigation 2-way travel times in milliseconds for channel #0 Jumps are due to multiplath arrivals.

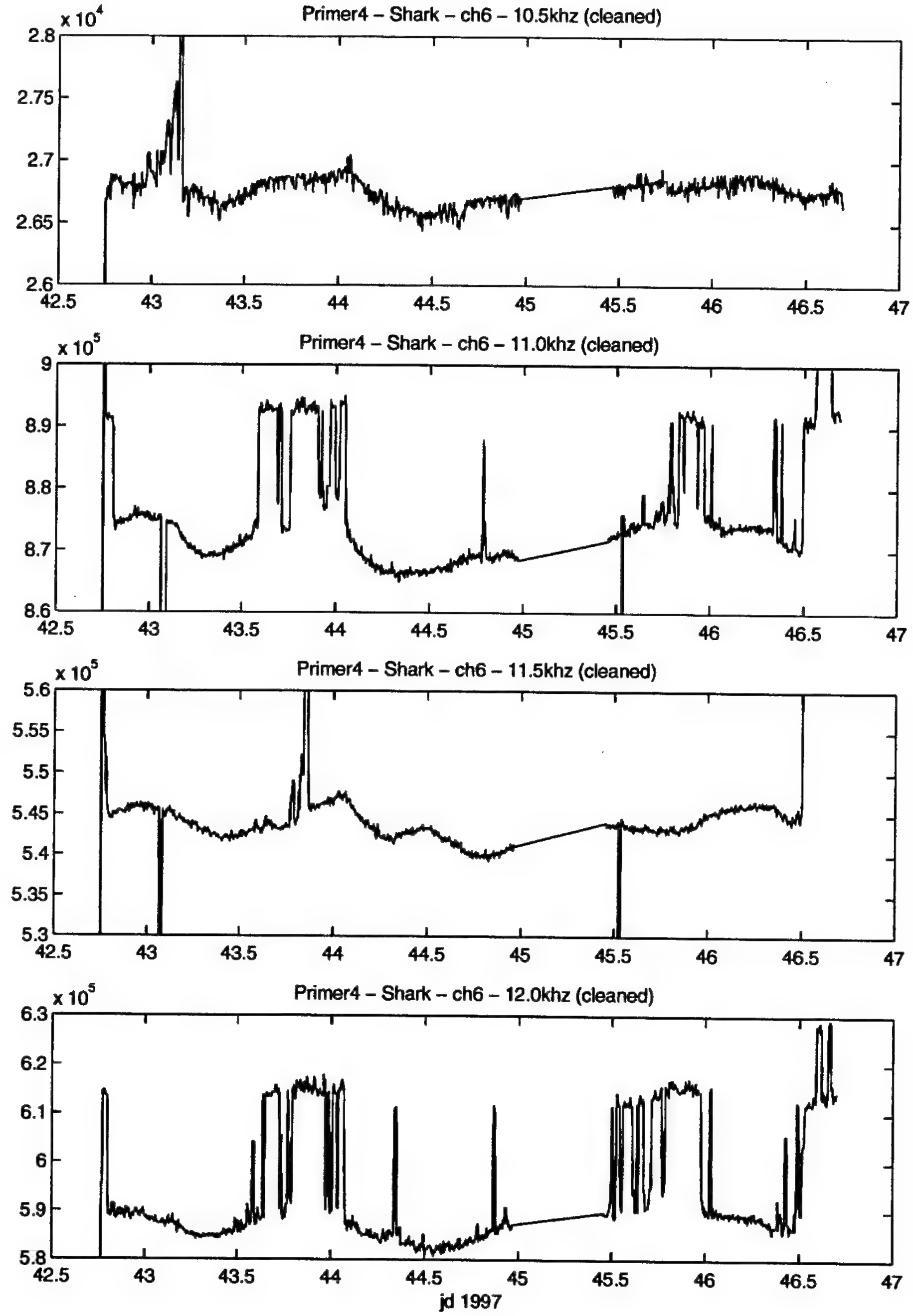


FIGURE 67. Shark internal navigation 2-way travel times in milliseconds for channel #6.

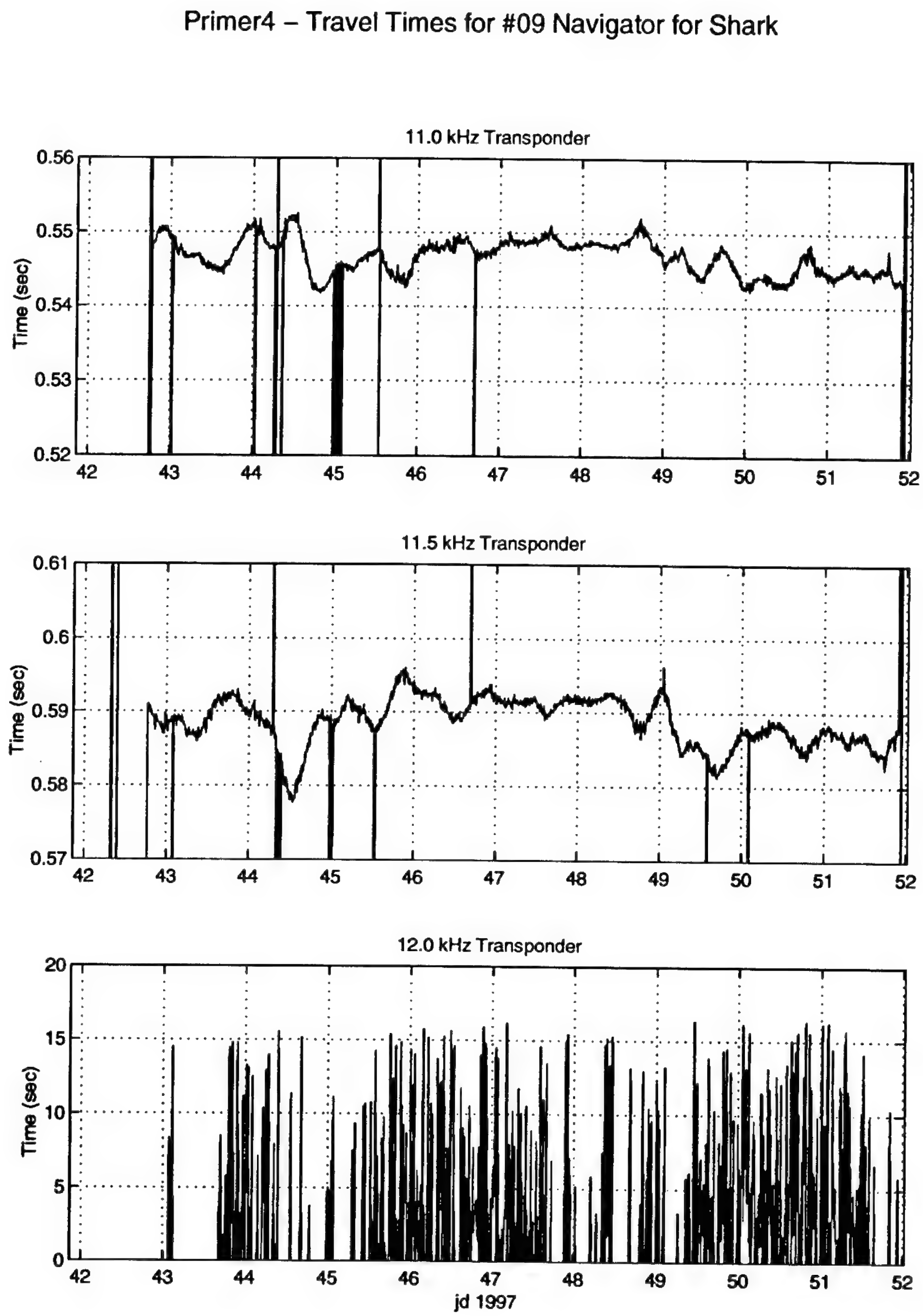


FIGURE 68. Travel times for Shark's external navigator.

2.7.3 "Shark of Science" data tape status

Acoustic date from Feb. 11th to Feb. 15th was saved from the Shark's internal disk to 8mm Exabyte data tapes. The data tape format is below. Data tape 00 has 18 data files, 4 of which have less than 300 records. All the other datafiles are full with 300 records. Data tape 01 has 17 data files. Three have less than the full 300 records. Data tape 02 has 15 data files. Three have less than the full records. Data tape 03 has 10 full data files and contains the last full record file named 02151529, which ends at 1647 hours.

TABLE 39. File starting times for shark data tape 00

02111605	02111803	02112000	02112158	02112315
02120113	02120137	02120147	02120152	02120350
02120416	02120530	02120727	02120925	02121122
02121320	02121517	02121715		

TABLE 40. File starting times for shark data tape 01

02121849	02122047	02122244	02130042	02130239
02130437	02130634	02130638	02130757	02130811
02131009	02131206	02131403	02131601	02131616
02131814	02132011			

TABLE 41. File starting times for shark data tape 02

02132132	02132329	02140127	02140324	02140522
02140719	02140917	02141052	02141249	02141447
02141512	02141710	02141907	02142105	02142302

TABLE 42. File starting times for Shark data tape 03

02150012	02150210	02150408	02150605	02150802
02151000	02151157	02151332	02151529	02151647

2.7.4 Data format for both acoustic arrays

Approximately 30GB of data were stored on disks aboard the WHOI VLA telemetry buoy (WVLA) and the "Shark of Science" (Shark) sled. The Shark data are essentially gap free except for the few seconds between partition swaps on a disk drive and as much as a minute between disk drive changes. In all but these and a very few other "non-problem"

cases involving recording breaks of a minute or so, data on any partition are seamless between files.

Data were subsequently copied while still aboard R/V Endeavor onto 8mm tape using Exabyte model 8505 drives. An additional 3 complete copies have been made, direct from the instruments' disk drives, in the lab at WHOI.

On the tapes the block size is always 1024 bytes and standard filemarks are used. The format of the Primer4 data tapes is nearly identical (the data portion of tapes is identical) to the Primer3. If data other than time/date/rec-length are desired from the Data Record Headers (DRH), review the data record header format shown below. All Primer4 tapes begin with the same 1K byte ``TAPE HEADER" followed by a filemark. The format of this tape header is:

```
  struct tape_header          /* 1024 bytes total              */
 {
    unsigned char hkey[4];    /* tape header key, "MTHD"        */
    unsigned char sn[16];     /* Tape S/N, 15 chars         */
    /* Tape S/N forms are: 96SHARK_dd_c \& 96BUOY_dd_c, dd=disk#, c=copy# */
    unsigned int  dhtime[4];  /* date/time header was written      */
    /* year, unsigned int; month/day, 2 packed unsigned chars         */
    /* hour/minute, unsigned int; second/millisecond, unsigned int    */
     unsigned char unused[880]; /* unused bytes                      */
     char        ayear[16];     /* year, ascii (1995)                */
     char        amonth[16];  /* month, ascii                        */
     char        aday[16];      /* month-day #, ascii                */
     char        ahour[16];     /* hours, ascii                      */
     char        aminute[16]; /* minutes, ascii                      */
     char        asec[16];      /* seconds, ascii                    */
     char        snl[16];       /* tape S/N, 15 chars                */
     unsigned char hkeyl[4]; /* repeat of tape header key ``MTHD" */
 };
```

A data file is a contiguous sequence of records, each beginning with a 1 Kbyte data record header (DRH), in which the record size, number of channels, acoustic navigation info, etc. are identified. The files are forced to be a length of about 2 hours in the interest of manageable size. Shark data was always acquired at 1395 Hz and has flat bandwidth of 523 Hz, (-3dB @572 Hz). On both systems, data are simultaneously sampled across all channels by an array of Sigma-Delta converters which apply an FIR filter of constant 28 sample period group delay. The exact sample rate is given by 5,000,000/7/256/2. Buoy data is at 3906.25 Hz sample rate with a flat bandwidth of 1465 Hz. Most files are 300 records (314880000 Bytes) in length. Data are normally seamless between such files but times should be checked.

Filenames are of the form mmddhhnn.DAT where mm = month, dd = day, hh = hour and nn = minute UTC, so a file's name approximates its start time to the minute.

Data records are always 1025 KBytes in length which includes the 1024 byte DRH. DRH information from both systems includes record number, time to the microsecond and some engineering data some of which is in both binary and ASCII form so it's possible to "figure out" where one is by viewing an ASCII representation of a DRH. Acoustic navigation data were not recorded on the Buoy array because of a yet to be discovered problem, but were recorded by the Shark system. One will note isolated inconsistencies in the Shark nav data because the backup nav interrogator at the top of the array occasionally pinged at the same time as the instrument driven bottom pinger, causing the transponder receptions to be garbled.

Following each DRH are multiplexed data consisting of an integral number of scans of all 16 channels. A data record containing WVLA data will be of the following form.

DRH <1024 bytes>,
VLA chan 0 value, chan 1 value, chan 2 value, ... ,VLA chan 15 value,
etc., an integral number of scans as well as 1024 byte blocks
DRH <1024 bytes>,
VLA chan 0 value, chan 1 value, chan 2 value, ... ,VLA chan 15 value,
etc., an integral number of scans as well as 1024 byte blocks

.

.

.

EOF

Data are stored as unsigned short (2 bytes), with the lower byte occurring first followed by the upper byte.The bits are high true, i.e an active bit is a ``one " or high logic level. The 16 bit sample consists of a 14 bit, 2's complement mantissa (M12 is msb), in the low part of the word with the 2 gain bits in the lower part, (G1 is msb). The sign bit is in the 15th bit position, (0 is positive). Bits 0 through 7 are the low byte and bits 8 through 15 are the high byte of the stored sample. The exponent represents effective gains of 1, 8, 64 and 512 with 00, 01, 10, and 11 respectively. These correspond to left shifts of 0, 3, 6 and 9 bits in the raw 23 bit magnitude.

```
Bit 15  14   13   12   11   10   09   08   07   06   05   04   03   02   01  00
    SN  M12  M11  M10  M09  M08  M07  M06  M05  M04  M03  M02  M01  M00  G1  G0
  {+/-}{            13 BIT MANTISSA                         } {`GAIN'}
```

There are always 32768 16 channel scans in a record. Following the last block of a record, will be the next DRH, followed by more data. Time to the microsecond of the first sample in any record and the record number are recorded in the record header as shown in the ``C structure" used to define the 1024 byte Data Record Header (DRH). The start time value wobbles about some (usually only a few milliseconds), due to the interrupt response time of the acquisition system. Note that number types are from the PC world where "ints" are shorts, 2 bytes, and "longs" are 4 bytes.

```
struct data_rec_hdr          /* 1024 bytes total                    */
{
```

```
unsigned char  rhkey[4];        /* header key, "DATA"                          */
unsigned int   date[2];         /* date[0]=year, date[1]=Year-day#             */
unsigned int   time[2];         /* time[0] = (hours*60 + minutes)              */
                                /* time[1] = (seconds*1000 + milliseconds)     */
unsigned int   microsec;        /* microseconds                                */
unsigned int   rec;             /* number of record that follows               */

unsigned int   ch;              /* # channels  <16>                            */
long           npts;            /* # sample periods per record <32768>         */
float          rhfs;            /* sample rate in Hz <1395.089286>             */
unsigned int   rlen;            /* rec length in blocks, includes DRH <1025>*/
long           rectime;         /* record time in microsec <??>                */

char           rhlat[16];       /* lat, ascii DDD MM SS.T  N or E <approx>  */
char           rhlng[16];       /* long, ascii DDD MM SS.T E or W <approx>  */

long           nav_data[16];    /* PRIMER-96 VLA acoustic nav data             */
                                /* The format is 4 groups of 4 long tt's       */
                                /* where the sequence in each group is         */
                                /* 10.5, 11.0, 11.5, 12.0  KHz TT's            */

long           nav_windows[4];  /* measured window times in microsecs          */
                                /* ch 0 (top), ch 6, ch 11, ch 15              */
unsigned char  unused1[612];    /* not used for PRIMER-96                      */

int            vit_flag;        /* no-zero indicates vit this record           */
unsigned int   vit_mh;
unsigned int   vit_ms;
int            nav_flag;        /* non-zero indicates nav this rec             */
unsigned int   nav_mh;          /* the time of the nav suite, mh               */
unsigned int   nav_ms;          /* the ms part of the time                     */

long      bw;                   /* LAN link BW in bytes/s for previous rec */
float     fit;                  /* float version of internal temp              */
float     fbv;                  /* float version of bat voltage                */
float     fbc;                  /* float version of bat current                */

char      internal_temp[16];    /* internal instrument temp, ascii             */
char      bat_voltage[16];      /* main battery voltage, ascii                 */
char      bat_current[16];      /* main battery current, ascii                 */
unsigned char  status[16];      /* for AD24 status bytes if marker bit err */

char      proj[16];             /* project name, ascii  <PRIMER>               */
char      exp[16];              /* ascii representation of Exp #               */
char      vla[16];              /* VLA sensitivity  <-170 db>                  */
char      hla[16];              /* HLA sensitivity  <-170 or 0 if not used> */
char      fname[16];            /* ascii file name  <mmddhhnn.dat>             */
```

```
char        record[16];        /* ascii representation of rec #, REC #### */
char        adate[16];         /* ascii representation of date, mo/da/yr */
char        atime[16];         /* ascii rep of rec time, hr:mn:ss.mmmmmm  */

char        unused2[4];
int         vit_period;        /* period in minutes of VIT update        */
int         nav_period;        /* acoustic nav period, min for PRIMER-96  */
int         adc_rate_code;     /* AD24 rate code, {6,5,4,3,2,1,0} <5>    */
int         adc_mode;          /* 0 =fixed point, 1 = 24 bit, 2 = pfp    */
int         adc_clk_code;      /* timebase divider to get AD24 clock     */
unsigned int scan_blocks;      /* # 512 pt scans per AD24                */

long        timebase;          /* 5000000 Hz                             */
long        xbuf_size;         /* xm space in use                        */
long        wr_xbuf;           /* ptr to first xm buffer, this record    */
long        rd_xbuf;           /* linear address of data buffer, this rec */

unsigned int xm_block_size;    /* size of block transfers to xm space/intr */
unsigned int xmbufs;           /* # xmspace buffers                      */
unsigned int xbufs_per_rec;    /* # xm_block_size chunks per record      */
char        data_error1;       /* tba                                    */
char        data_error2;       /* tba                                    */
char        ovf;               /* data buffer overflow count             */
char        tbufs;             /* # rec/time buffers (max ip_flag, op_flag */
char        ip_flag;           /* input buffer #                         */
char        op_flag;           /* output buffer #                        */
char        rhkeyl[4];         /* end of rec header key "DATA"           */
};
```

Sample rate is a function of the Delta-Sigma ADC architecture and the ADC clock. The Buoy has some flexibility to change divider ratios to change the rate; however all data were at the 1395 kHz rate.

For each data file, there exists an ASCII log file which contains the status information available at the time each record is stored. Among the information logged in this file is the acoustic NAV data. A copy of these log files for both the Buoy and the Shark are on a tape as part of each data copy. It is much easier to extract the NAV data from these files rather than the data tapes. Logfile excerpts from both Shark and Buoy are shown. Note the large MAX/MIN values from CH 15, at the bottom of the VLA. The NAV pinger output is responsible for the higher than normal levels which are given in volts output from the sensor. The same symptom is evident on CH 0 on both arrays when the interrogator just beneath the subsurface float fires. The sensor sensitivity is -170 dBV re 1V/muPa and is capable of a maximum linear output of 1Vpp, corresponding to a pressure peak of 160dB re 1 muPa. A NAV suite occurred every 4 minutes starting at 2 minutes after the hour. The interrogator at the VLA top initiated a cycle every 5 min on the hour. The NAV data are shown in microseconds as a measurement of the roundtrip traveltime from the pinger at the base of the VLA to the transponder and back to the selected VLA channel. The times

measured include the "turn-around time" for the Benthos transponder and the recognition-time for the Sonatech detectors used at the Shark. The Sonatech recognition time has been shown to be about 4 ms with a jitter of less than .2 ms.

At the 4 minute interval, the time is reported in the logfile after "NAV INTR @....", the 10.5 KHz pinger (in the SHARK sled it was about .5m above the bottom) was triggered to emit a sequence of 4 - 10ms tone bursts with an SPL of about 185 dB, each separated by 5.00 seconds. At each occurrence of the trigger, a timer with microsecond resolution and at least 10 microseconds accuracy was started for all 4 detectors.

All 3 transponders respond as they hear the 10.5 KHz ping.

Ch 0 (TOP), 6, 11, and 15 are sequentially connected to the 4 ch detector with the time of the first detection for each of the 4 frequencies logged during each of 4 - 5 second detect windows. Therefore, it takes 20 seconds to complete a NAV interrogation suite. The low frequency data acquisition was uninterrupted.

After the completion of a NAV sequence, the NAV system was dormant until the next 4 min interval had elapsed. Nominally, NAV times should have been @ 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, and 54 min after the hour.

Sample Shark logfile from Primer3 at the beginning of a file:

```
NEW FILE C:07240344.dat @rec 1200, disk space = 32866304
R 1200 ov00 op00 ip01 TIME 03:44:28.697 23488103 -0037953 02097152 02564096
Unit 00 disk C:  space = 32866304,  Status:  00  00  00  00
MAX @ ch 12  0.003212  MIN @ ch 4  -0.002159

R 1201 ov00 op01 ip02 TIME 03:44:52.185 23488103 -0037953 03145728 03612672
Unit 00 disk C:  space = 31784960,  Status:  00  00  00  00
MAX @ ch 0  0.015106  MIN @ ch 0  -0.029960

R 1202 ov00 op02 ip03 TIME 03:45:15.673 23488103 -0037952 04194304 04661248
Unit 00 disk C:  space = 30703616,  Status:  00  00  00  00
MAX @ ch 9  0.003238  MIN @ ch 4  -0.002620

R 1203 ov00 op03 ip04 TIME 03:45:39.162 23488101 -0037954 05242880 05709824
Unit 00 disk C:  space = 29655040,  Status:  00  00  00  00
MAX @ ch 15  0.119268  MIN @ ch 15  -0.114873

NAV INTR @ 03:46:00.000524.....(ch 0 is top)
ch 00    0039624 0961414 0406879 0719174
ch 06    0026859 0960820 0405201 0718366
ch 11    0013452 0959555 0404446 0716962
ch 15    0007692 0958858 0403760 0717206
10.5 win=5032460  11.0 win=5035894  11.5 win=5000338  12.0 win=5000412
```

R 1204 ov00 op04 ip05 TIME 03:46:02.650 23488104 -0037952 06291456 06758400
Unit 00 disk C: space = 28606464, Status: 00 00 00 00
MAX @ ch 15 0.116455 MIN @ ch 15 -0.113994

An excerpt from a Buoy data file from Primer3 is shown. The "VIT" line shows the time of a measurement of battery voltage, battery current in amps, and the internal temperature of the BUOY taken at a point next to the DX40 CPU, degrees C. Again the high level at the bottom sensor is evident when the NAV pinger fires. The lack of NAV data is evident as well.

R 1808 ov00 op08 ip09 TIME 17:33:27.501 23488102 -0000679 10485760 10752000
Unit 00 disk C: space = 245825536, Status: 00 00 00 00
MAX @ ch 1 0.009503 MIN @ ch 12 -0.008616

VIT: 17:34:00.000: Voltage=32.2 Current=1.503 Temp=31.9

NAV INTR @ 17:34:00.000536....
ch 0 0000000 0000000 0000000 0000000
ch 1 0000000 0000000 0000000 0000000
ch 2 0000000 0000000 0000000 0000000
ch 3 0000000 0000000 0000000 0000000
10.5 win=5000405 11.0 win=5000286 11.5 win=5004038 12.0 win=5020464

R 1809 ov00 op09 ip10 TIME 17:33:50.989 23488104 -0000677 11534336 11804672
Unit 00 disk C: space = 244776960, Status: 00 00 00 00
MAX @ ch 15 0.080629 MIN @ ch 15 -0.084990

R 1810 ov00 op10 ip11 TIME 17:34:14.477 23488101 -0000678 12582912 12849152
Unit 00 disk C: space = 243728384, Status: 00 00 00 00
MAX @ ch 15 0.076827 MIN @ ch 15 -0.084133

VIT: 17:35:00.000: Voltage=32.2 Current=1.298 Temp=31.9

R 1811 ov00 op11 ip12 TIME 17:34:37.965 23488102 -0000679 13631488 13897728
Unit 00 disk C: space = 242679808, Status: 00 00 00 00
MAX @ ch 8 0.007560 MIN @ ch 2 -0.008065

The realtime clock in both systems were synchronized to UTC provided by the shipboard GPS clock. Prior to deployment a time offset was recorded. Subsequent to recovery, the time offset was again measured so that an average clock drift rate can be estimated.

These data are:
Shark
Rel UTC before deployment: @ 7/23, day 205 1430Z....SHARK lags UTC by 0.76 ms
after recovery: @ 8/04, day 217 1237Z....SHARK lags UTC by 5.20 ms
corresponding to about 4.3 parts in 10e9 or about 370 microseconds/day, average.

WVLA
Rel UTC before deployment: @ 7/23, day 205 1430Z....BUOY lags UTC by 0.44 ms
after recovery: @ 8/05, day 218 1435Z....BUOY lags UTC by 4.65 ms
corresponds to about 3.75 parts in 10e9 or about 325 microseconds/day, average

The relationship between Sample_O/P_Rate and BW is:
Sample_O/P Rate = (CLOCK / 256) / (2**(6-ADC_Rate_Code))

The relationship for flat DATA BW (Hz) and Sample_O/P_Rate is:
BW = .375 * Sample_O/P_Rate

The relationship between Flat BW and storage/telemetry rate is:
Telemetry_Rate = (BW / .375) * CHANNELS * 2

The CLK frequency is the Austron 5 MHz output divided by ``n".

Data can be normalized to volts at the output of the sensor as follows:
The 2 bit gain code represents up to 3 - 3-bit left shifts of the original 24 bit ADC word.
This can be treated as exponent = 1 << ((stored value & 0x03) * 3).

mantissa = (value >> 2)} (13 bits and sign bit)

Differential amp fixed gain = 10

Full scale digital value of ADC is 5242880. Hence, the factor .625 results from 5242880/(2**23)

Full scale ADC input voltage is {\em+/-4.5}

Hence: normalized value = (4.5 * mantissa)/(2**13)/.625/exponent/10

"C" code that to do this is:

```
exp = 1 << ((p[i]&0x03*3);     /* where p[i] is a raw data value */
fprintf(outfile, "%08f\n", (double)(p[i]>>2)*4.5/8192/exp/.625/gain);
```

2.8 SUS charges

To provide broadband acoustic transmissions that can be inverted for both water column and ocean bottom soundspeed profiles, Mark 61 1.8 lb explosive charges were dropped from a NAWC P-3 aircraft. The charges were set to detonate at 18 meters depth and were dropped along lines both inside and outside the tomography area. Conventional tomography provides a longer time series over a smaller area while the SUS drop provides a temporal "snapshot" over a larger spatial area and over a larger acoustic bandwidth. These

positions were taken directly form the NAWC Air Ops log book. The longitude position may not be accurate enough for our analysis since they are all the same. Some SUS runs were performed west to east at a single latitude. The longitude positions should have changed.

TABLE 43. Feb 19, 1997 SUS drop times and locations from NAWC Air Ops.

time hhmmss	**Latitude degrees N**	**Longitude degrees W**	**Remarks**
175040	71.13	40.37	rev1 - good
175827	71.14	40.37	rev1 - good
180325	71.13	40.37	rev2 - good
181029	71.13	40.37	rev2 - good
181525	71.13	40.37	rev3 - good
182252	71.14	40.37	rev3 - good
182833	71.12	40.37	rev4 - good
183558	71.12	40.37	rev4 - good
185542	71.14	40.37	run1 - good
185607	71.14	40.37	run1 - good
185623	71.14	40.37	run1 - good
185642	71.13	40.37	run1 - good
185702	71.13	40.37	run1 - good
185721	71.13	40.37	run1 - good
185742	71.13	40.37	run1 - good
185803	71.14	40.37	run1 - good
18582	71.14	40.37	run1 - good
185842	71.15	40.37	run1 - good
185902	71.15	40.37	run1 - good
185923	71.15	40.37	run1 - good
185944	71.15	40.37	run1 - good
190002	71.15	40.37	run1 - good
190023	71.16	40.37	run1 - bad
190042	71.16	40.37	run1 - good
190103	71.16	40.37	run1 - good
190123	71.16	40.37	run1 - good
190143	71.16	40.37	run1 - bad
190201	71.16	40.37	run1 - good
190223	71.15	40.37	run1 - good
190243	71.15	40.37	run1 - good
190302	71.15	40.37	run1 - good
190321	71.15	40.37	run1 - good

TABLE 43. Feb 19, 1997 SUS drop times and locations from NAWC Air Ops.

time hhmmss	Latitude degrees N	Longitude degrees W	Remarks
190342	71.15	40.37	run1 - good
191122	71.15	40.37	run2 - good
191145	71.12	40.37	run2 - good
19120	71.10	40.37	run2 - good
191223	71.08	40.37	run2 - good
191244	71.05	40.37	run2 - good
191304	71.03	40.37	run2 - good
191323	71.01	40.37	run2 - good
191344	70.99	40.37	run2 - good
191404	70.97	40.37	run2 - good
191423	70.94	40.37	run2 - good
191443	70.92	40.37	run2 - good
191506	70.90	40.37	run2 - good
192757	71.15	40.37	run3 - bad
192819	71.12	40.37	run3 - good
192838	71.10	40.37	run3 - good
192858	71.08	40.37	run3 - good
192917	71.06	40.37	run3 - good
192937	71.04	40.37	run3 - good
192958	71.01	40.37	run3 - good
193019	70.99	40.37	run3 - good
193037	70.97	40.37	run3 - good
193058	70.95	40.37	run3 - good
193117	70.92	40.37	run3 - good
193140	70.90	40.37	run3 - good
194204	71.14	40.37	add1 - good
194343	71.13	40.37	add1 - good
194525	71.13	40.37	add1 - good
194704	71.13	40.37	add1 - good
194846	71.13	40.37	add1 - good

2.9 Vertical CTD casts

Twenty one stationary, vertical CTD casts (figs 69-74) were performed during legs 1 and 2 of Primer4. These were generally done while poor weather conditions prohibited mooring deployment or recovery. An additional section was performed during the July 1997 source pickup cruise (figs 75-77)

TABLE 44. Vertical CTD casts

cast	date	latitude (N)	longitude (W)	depth (m)	section
1	2/10/97	39 59.8833	71 11.2333	285	1
2	2/10/97	39 59.8833	71 11.2333	520	1
3	2/10/97	39 57.3000	71 10.0667	384	1
4	2/10/97	40 02.3167	71 10.1333	225	1
5	2/10/97	39 59.550	70 44.9300	296	2
6	2/10/97	40 05.600	70 45.6000	135	2
7	2/10/97	40 09.8600	70 45.0000	126	2
8	2/10/97	40 14.79	70 45.00	118	2
9	2/10/97	40 20.05	70 45.03	97	2
10	2/10/97	40 22.033	70 45.05	90	2
11	2/10/97	40 27.05	70 45.03	78	2
12	2/11/97	40 22.0733	70 40.0867	n/a	
13	2/15/97	40 21.9667	71 12.9167	n/a	3
14	2/15/97	40 19.900	71 10.050	n/a	3
15	2/15/97	40 16.0333	71 10.050	n/a	3
16	2/15/97	40 11.980	71 10.050	n/a	3
17	2/15/97	40 08.000	71 10.050	n/a	3
18	2/15/97	40 04.000	71 10.0333	n/a	3
19	2/16/97	40 22.0733	70 40.0867	n/a	
20	2/16/97	39 54.2700	71 11.4400	n/a	
21	2/16/97	39 53.0200	71 10.3867	n/a	

TABLE 45. Vertical CTD casts from July 1997 source pickup.

file #	date	time (Z)	latitude (N)	longitude (W)	depth
1	7/19/97	20:55:14	39 57.06	071 09.81	500
2	7/19/97	22:06:55	39 59.15	71 9.11	317.5
3	7/19/97	n/a	39 59.15	71 9.11	317.5
4	7/19/97	23:54:54	40 3.06	71 8.69	210.7
5	7/20/97	00:33:39	40 4.83	71 8.54	179.9
6	7/20/97	01:09:37	40 6.80	71 8.09	153.5
7	7/20/97	01:46:02	40 8.82	71 7.68	136.5
8	7/20/97	02:19:56	40 10.82	71 7.40	124.75
9	7/20/97	02:54:31	40 12.75	71 7.09	115.8
10	7/20/97	03:26:42	40 14.76	71 6.72	105.1
11	7/20/97	03:53:34	40 16.76	71 6.30	95.0
12	7/20/97	04:20:39	40 18.71	71 5.89	90.5

TABLE 45. Vertical CTD casts from July 1997 source pickup.

file #	date	time (Z)	latitude (N)	longitude (W)	depth
13	7/20/97	04:47:05	40 20.75	71 5.51	87.1
14	7/20/97	05:11:16	40 22.72	71 5.08	83.4

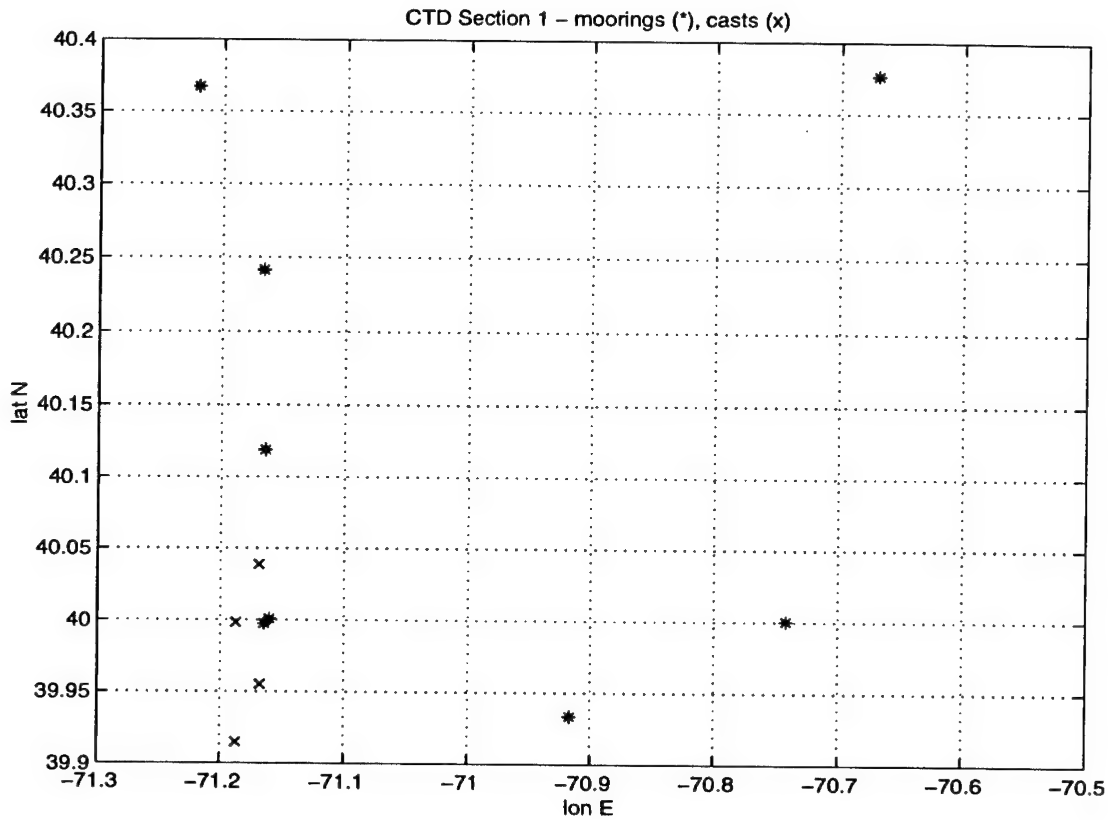


FIGURE 69. CTD section 1 locations - Western leg on Feb 10

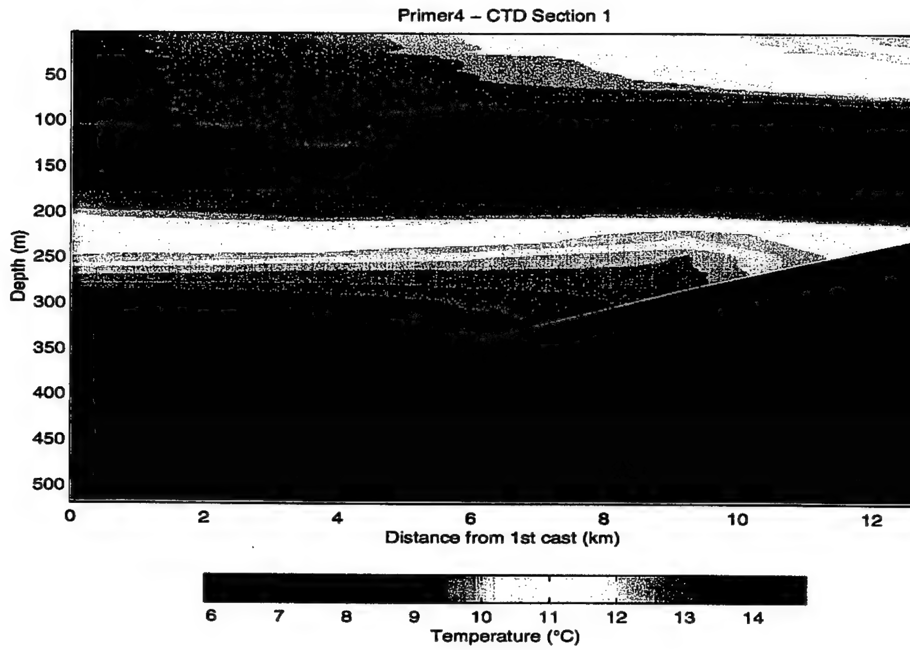


FIGURE 70. CTD temperatures for section 1 on Feb 10 at 1100 hrs (Z).

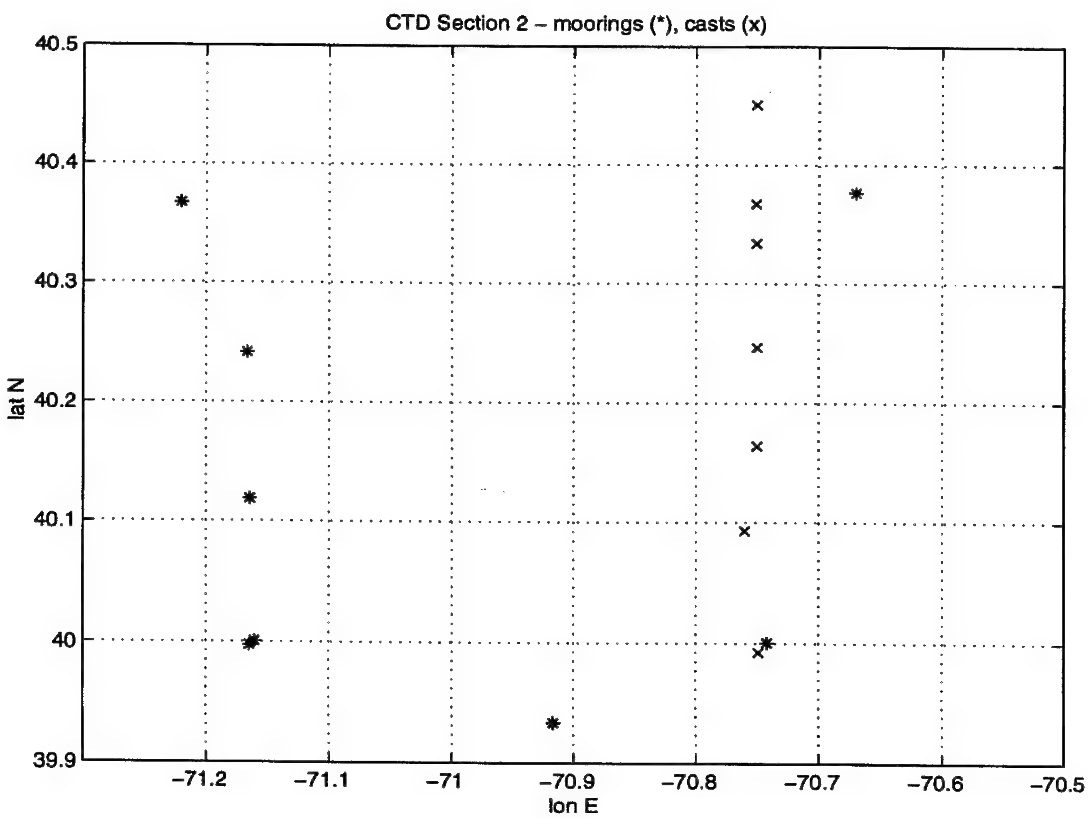


FIGURE 71. CTD section 2 locations - Eastern leg

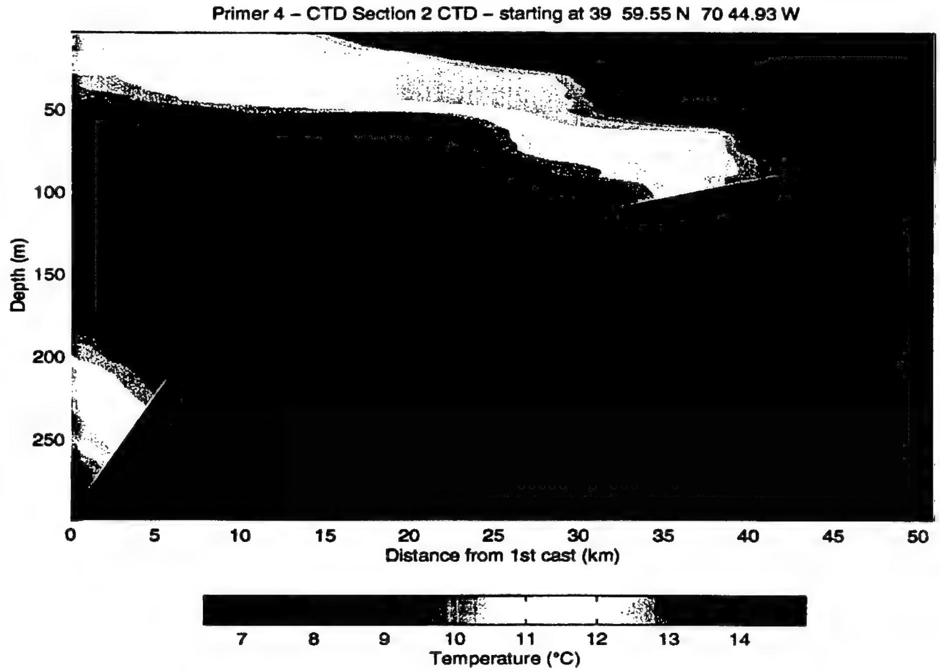


FIGURE 72. CTD temperatures for section 2 on Feb 11 at 0700 (Z)

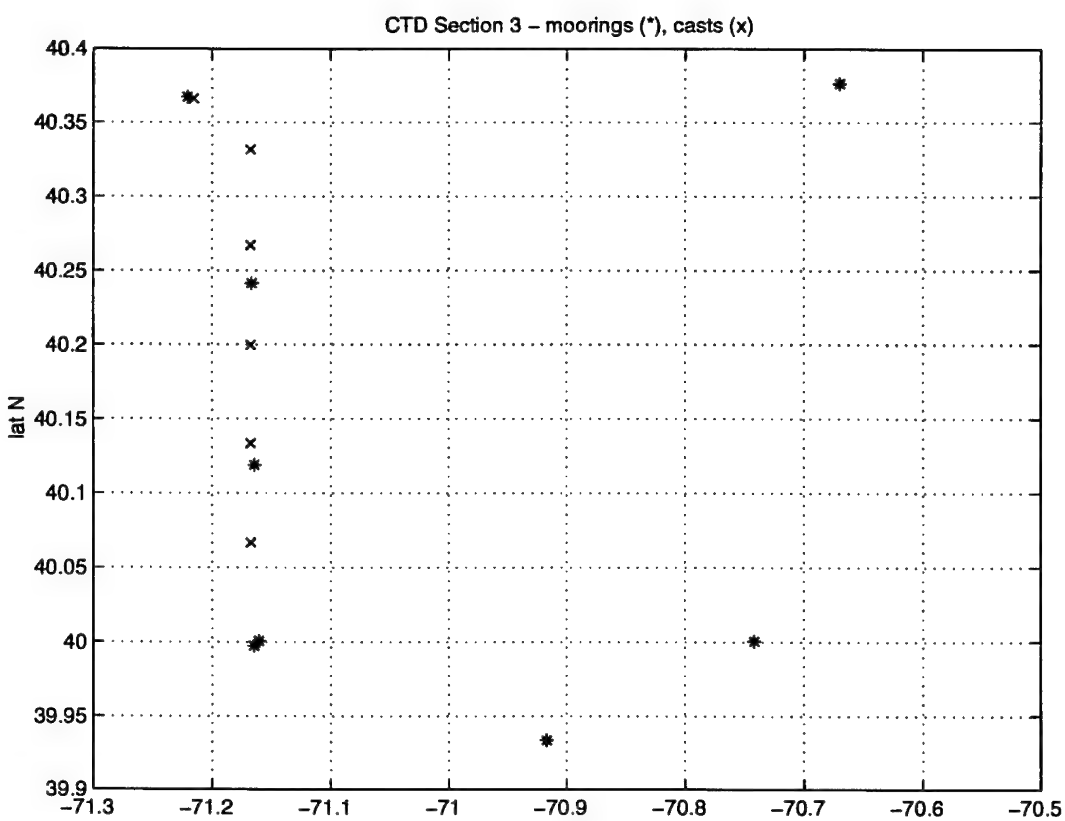


FIGURE 73. CTD section 3 - Western leg on Feb 15

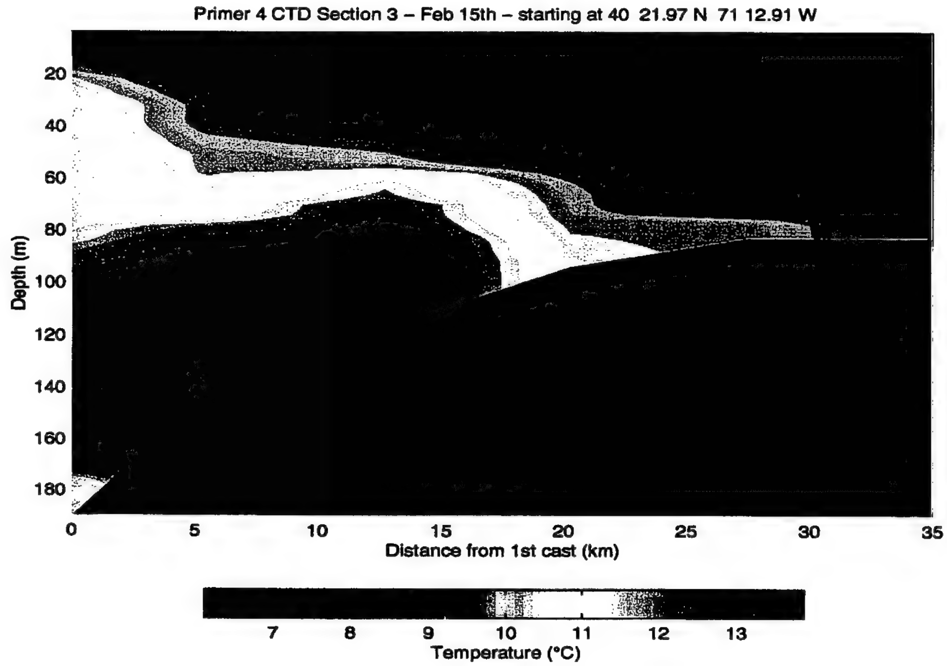


FIGURE 74. CTD temperatures for section 3 on Feb 15 at 2200 hrs (Z).

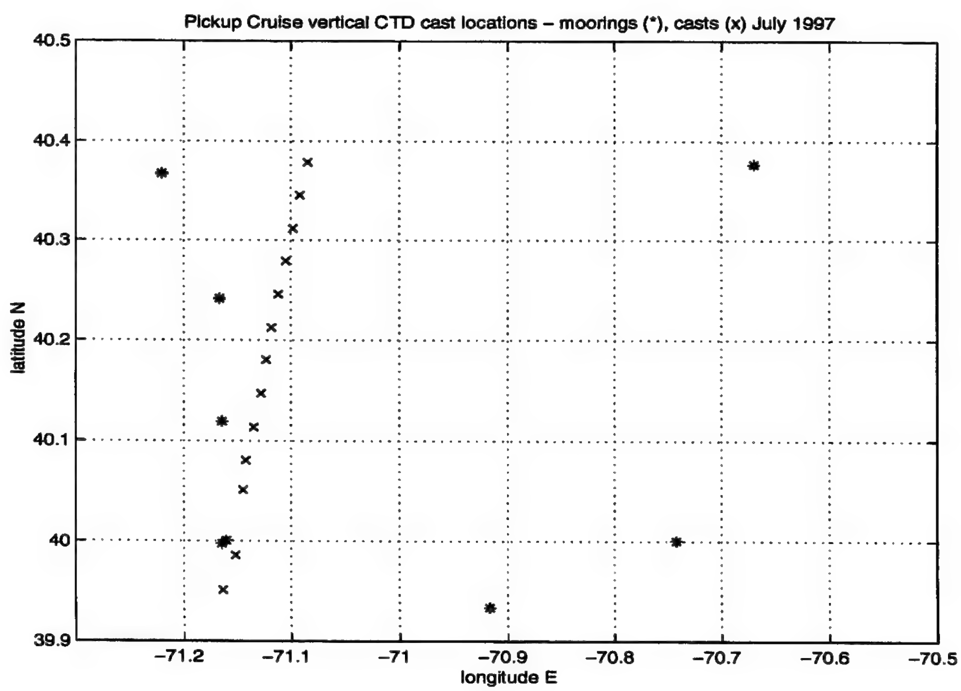


FIGURE 75. CTD locations from July pickup cruise.

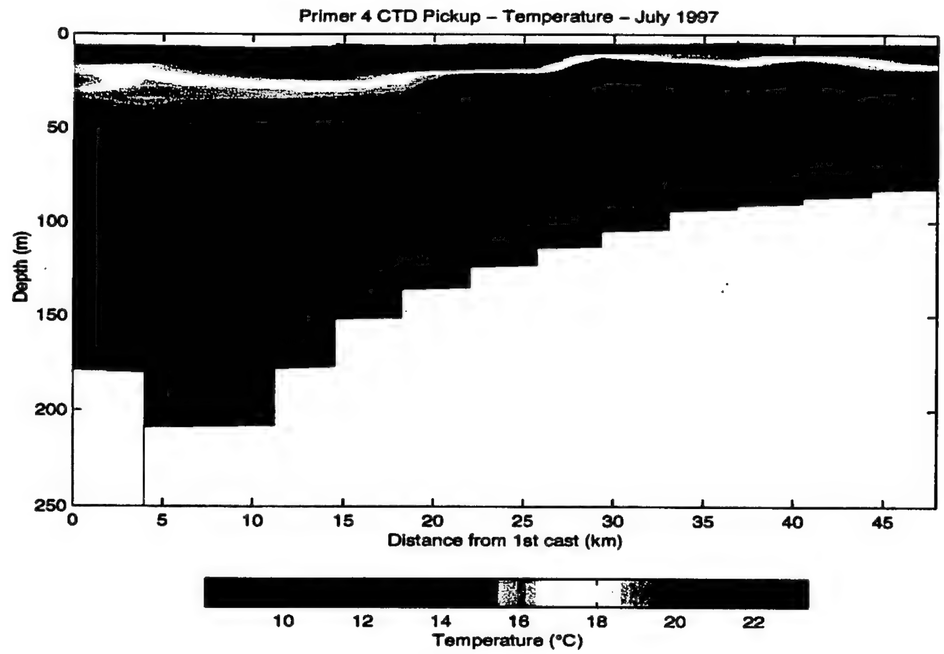


FIGURE 76. CTD pickup temperatures.

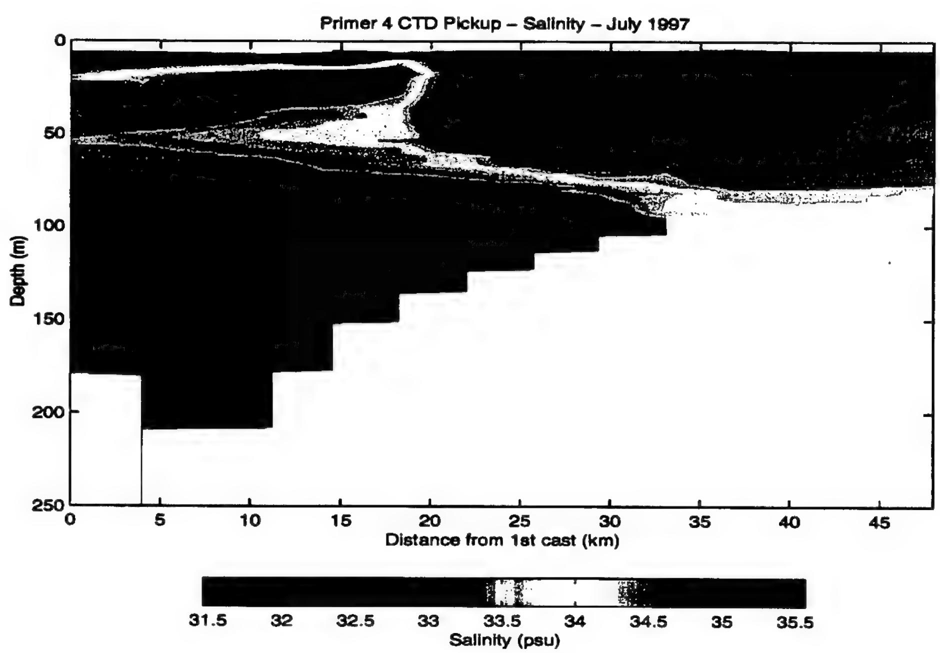


FIGURE 77. Pickup CTD salinity.

2.10 Shipboard met/navigation/chirp data

The R/V Endeavor had many on-board sensors which acquired data continuously throughout the cruise; Chirp sonar data, meteorological data, and ship navigation data. The chirp sonar data was on continuously except when acoustically interrogating instruments. We have 15 DAT tapes that contain approximately 27 chirp data files on each. Windspeed (fig 78) and chirp sonar bottom depths (fig 79) were used as initial data confirmation. All hull mounted instruments (adcp, chirp,...) have a nominal depth of 5 meters.

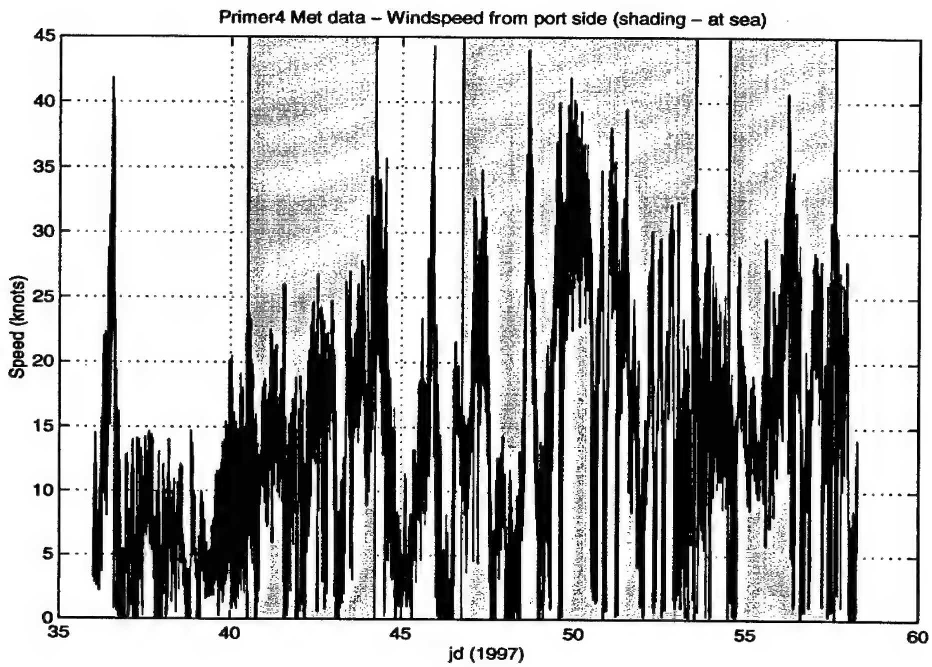


FIGURE 78. Windspeed from R/V Endeavor met data. Shading shows days at sea.

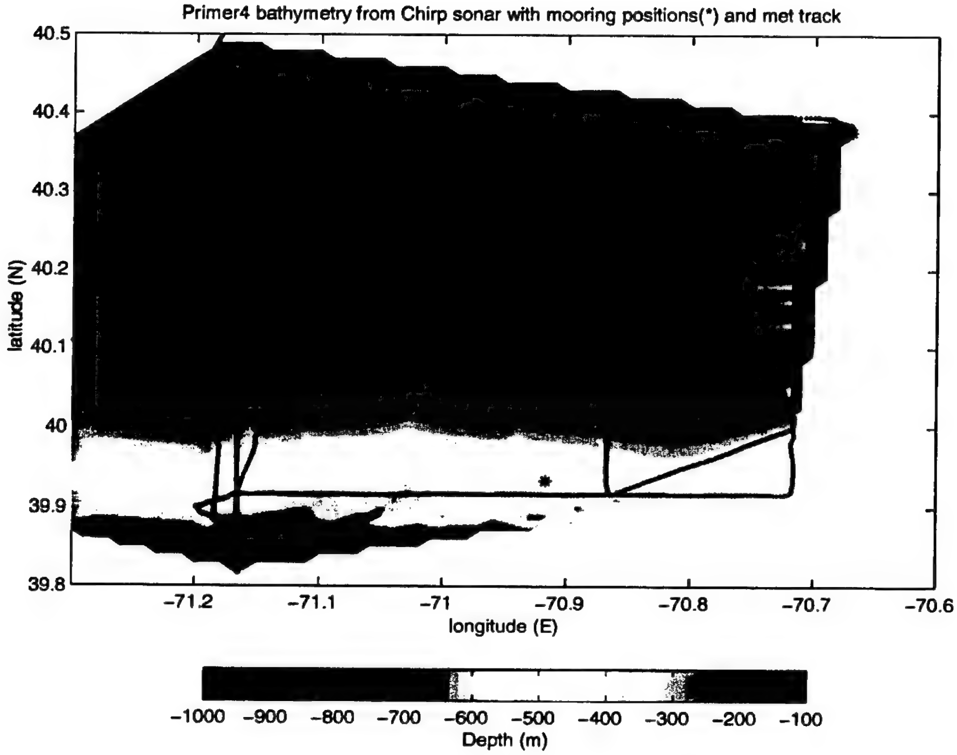


FIGURE 79. Bathymetry acquired by Chirp sonar.

Met data and format:

Sample frequency = 60 seconds
New file frequency = 24 hours
Data item count = 30

1) MAGELLAN 5000DX GPS
Magellan GPS UTC of fix

2) MAGELLAN 5000DX GPS
Magellan GPS north latitude

3) MAGELLAN 5000DX GPS
Magellan GPS west longitude

4) MAGELLAN 5000DX GPS
Magellan GPS quality indicator
  0 = fix not available or invalid
  1 = non differential fix
  2 = differential fix

5) MAGELLAN 5000DX GPS
Magellan GPS speed made good in knots

6) MAGELLAN 5000DX GPS
Magellan GPS course made good in degrees true

7) TRIMBLE NAVTRAC GPS
Trimble GPS UTC of fix

8) TRIMBLE NAVTRAC GPS
Trimble GPS north latitude

9) TRIMBLE NAVTRAC GPS
Trimble GPS west longitude

10) TRIMBLE NAVTRAC GPS
Trimble GPS quality indicator
  0 = fix not available or invalid
  1 = non differential fix
  2 = differential fix

11) TRIMBLE NAVTRAC GPS
Trimble GPS speed made good in knots

12) TRIMBLE NAVTRAC GPS
Trimble GPS course made good in degrees true

13) RM YOUNG TRANSLATOR
Port apparent wind speed in knots

14) RM YOUNG TRANSLATOR
Starboard apparent wind speed in knots

15) RM YOUNG TRANSLATOR
Port apparent wind azimuth in degrees

16) RM YOUNG TRANSLATOR
Starboard apparent wind azimuth in degrees

17) RM YOUNG TRANSLATOR
Air temperature in degrees C

18) RM YOUNG TRANSLATOR
Relative humidity in percent

19) RM YOUNG TRANSLATOR
Barometric pressure in millibars

20) RM YOUNG TRANSLATOR
Sea surface temperature in degrees C measured at transducer
well 5 meters below surface

21) EDO SPEED LOG
EDO speed log forward velocity with respect to water or bottom

22) RM YOUNG TRANSLATOR

Eppley PIR, long wave radiation in W/m^2
SN = 30606F3, calibrated 20 December 1995

23) RM YOUNG TRANSLATOR
Eppley PSP, global sun and sky radiation (short wave) in W/m^2
SN = 30600F3, calibrated 20 December 1995

24) EDO SPEED LOG
EDO speed log depth below transducer in meters

25) GYRO 1 $HEHDT 1
Gyro 1 (starboard), ship's head in degrees true

26) GYRO 2 $HEHDT 1
Gyro 2 (port), ship's head in degrees true

27) RM YOUNG TRANSLATOR
Sea surface temperature in degrees C measured at ship's
hull 1 meter below surface

28) CHIRP SONAR
EG&G Chirp Sonar depth below transducer in meters

29) EDO SPEED LOG
EDO speed log tracking mode
A = water track
V = bottom track

30) System Time 0
Decimal yearday

2.11 Satellite IR images

Throughout the entire cruise, satellite sea surface temperature data was collected to get spatial information on mesoscale oceanographic features. WHOI's Mike Caruso collected satellite sea surface temperature information from the National Oceanic and Atmospheric Administration (NOAA) Coastwatch Program while the experiment was in progress. A warm core ring (figs 80-82) remained within the study area for the duration and influenced much of the data we collected.

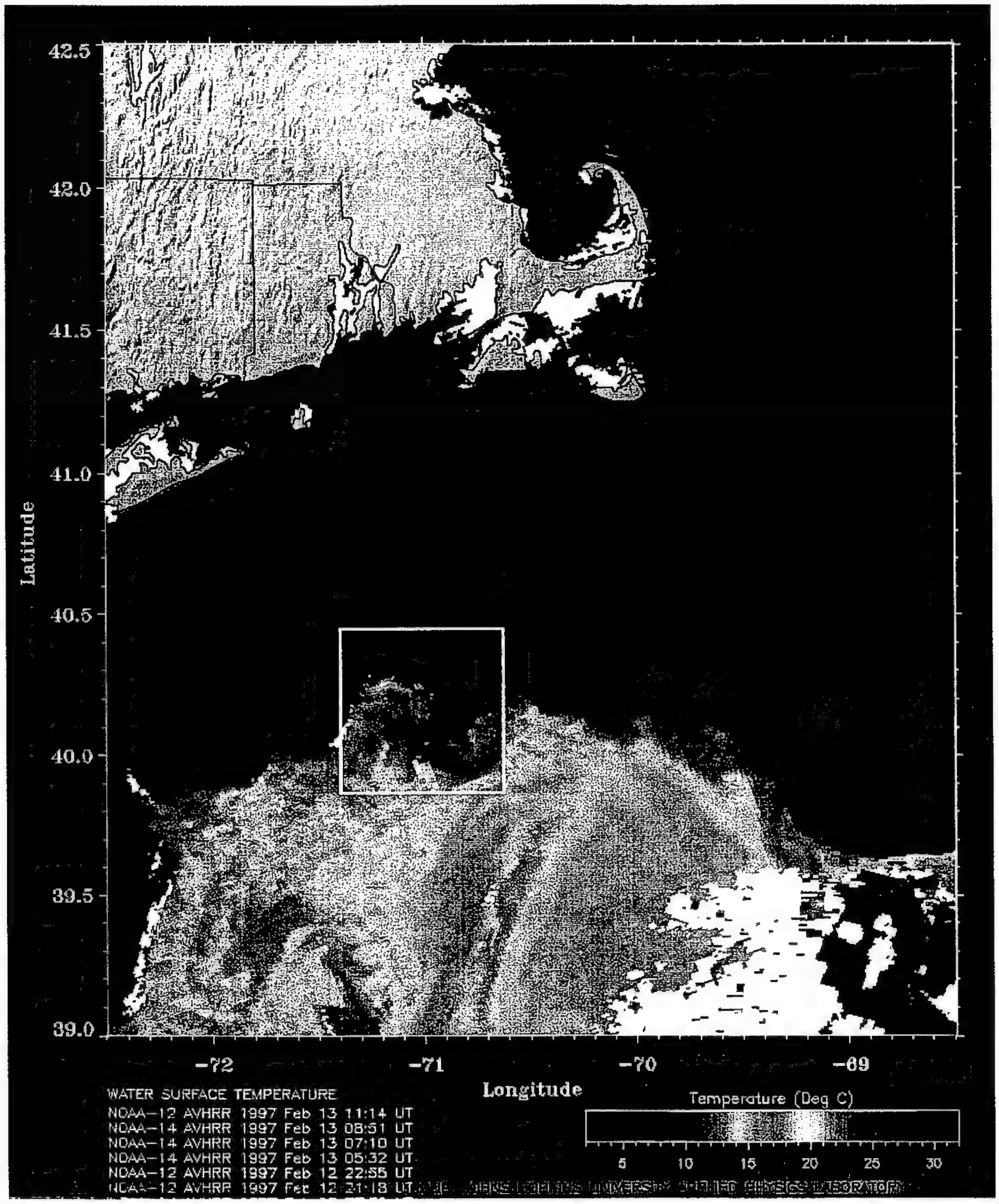


FIGURE 80. Sea surface temperature for Feb 13th from the Ocean Remote Sensing Group at John Hopkins University.The box indicates the Primer area of study.

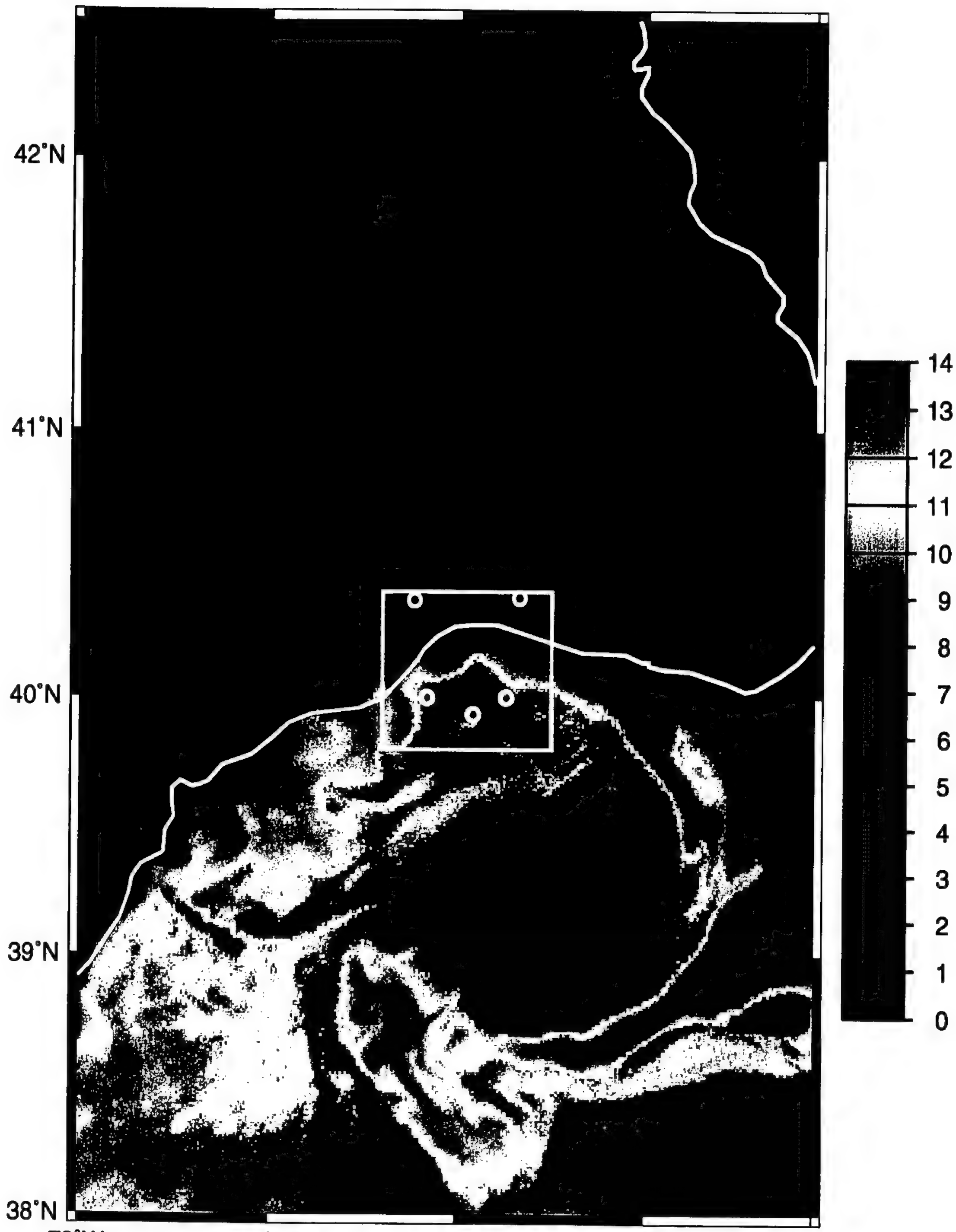


FIGURE 81. Sea surface temperature for Feb 18th courtesy of Mike Caruso. White line is the 100 meter isobath and the box is the area of study. The circles mark the acoustic moorings. Temperature color levels are in degrees C.

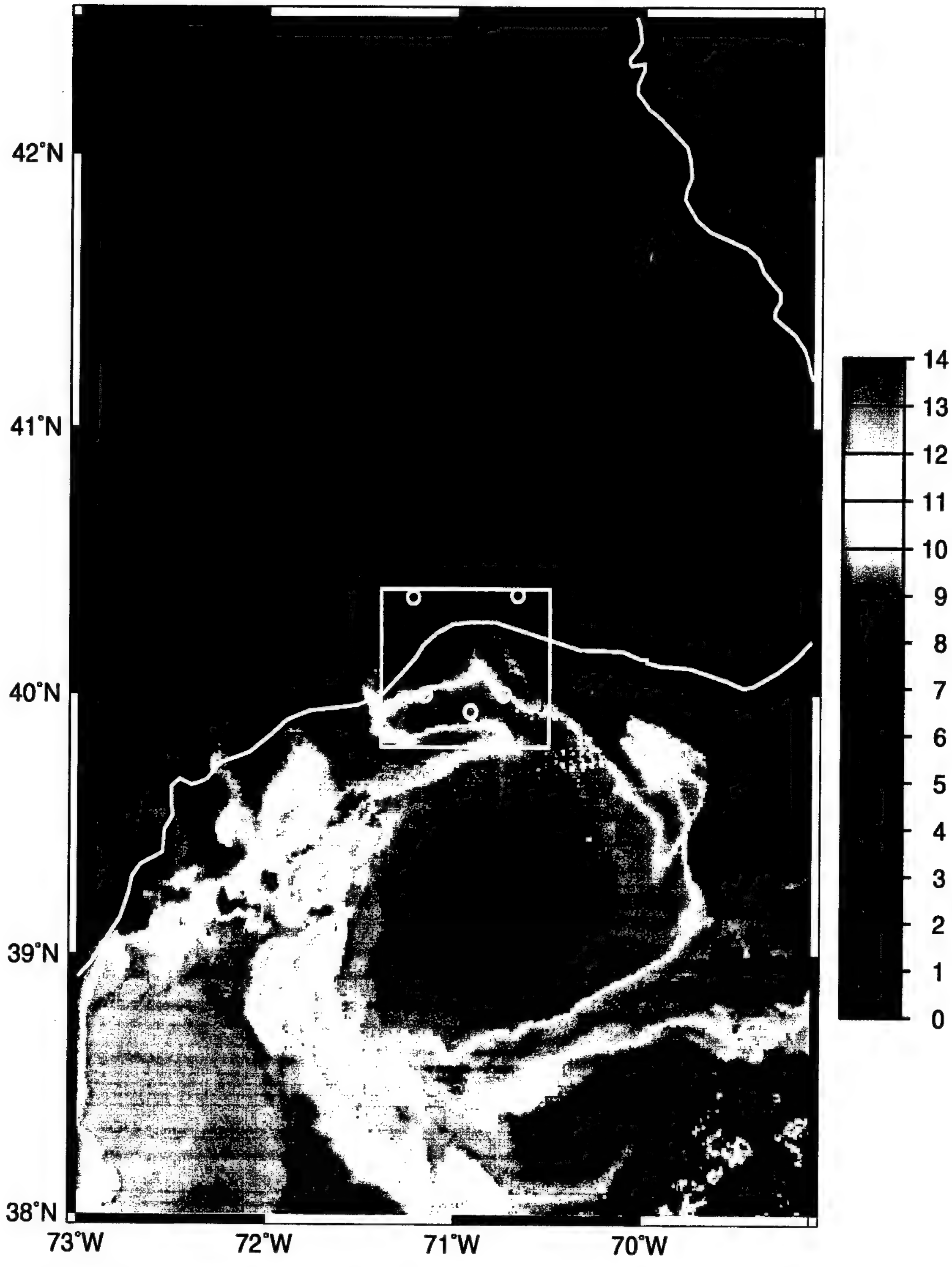


FIGURE 82. Sea Surface temperature for Feb 21st courtesy of Mike Caruso. The white line is the 100 meter isobath and the box is the area of study. The circles mark the acoustic moorings. Temperature color levels are in degrees C.

3.0 Field Deployment And Observations

3.1 Weather

The weather at the Primer4 site was typical of February in the North Atlantic - cold and windy. All deck work was conducted during windows of opportunity when the winds were light and the seas were comparatively low.

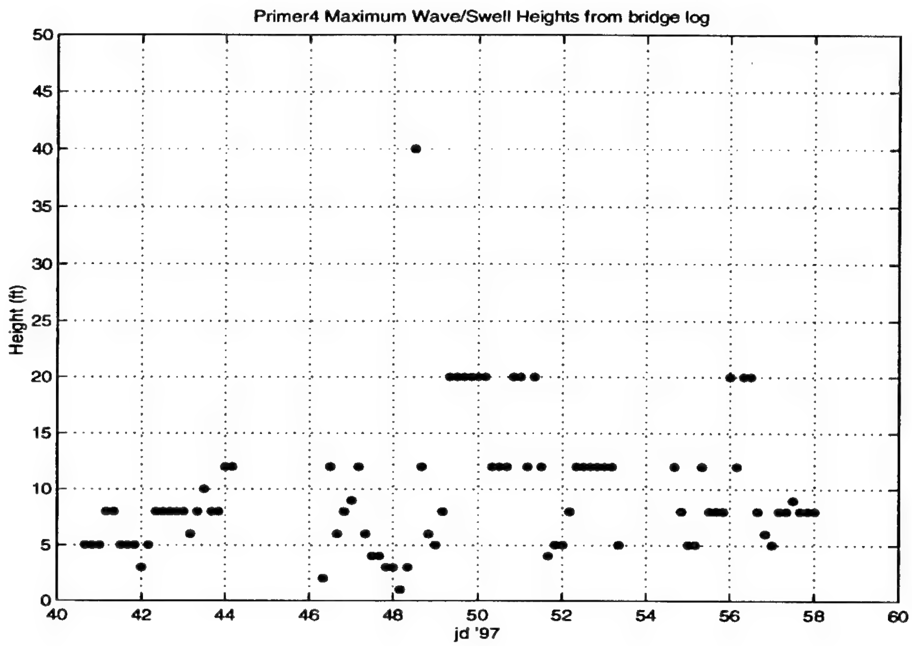


FIGURE 83. Maximum wave/swell heights observed from the R/V Endeavor bridge.

TABLE 46. Primer4 weather and sea state taken from bridge log.

date	local time (hrs)	weather	visibility (miles)	Wind dir. (deg N)	wind speed (knots)	sea direction (deg N)	sea heigth (ft)	swell direction (deg N)	swell height (ft)	Air temp (deg F)	water temp (deg F)
Feb 9	1600	bc	12	45.0	11-16	45.0	3-5	45.0	3	35	31
Feb 9	2000	bc	12	67.5	11-16	45.0	3-5	225.0	5	35	30
Feb 9	2400	clr	12	22.5	17-21	45.0	3-5	45.0	5	36	32
Feb 10	0400	bc	12	67.5	17-21	67.5	5-8	67.5	5	36	32
Feb 10	0800	bc	12	67.5	17-21	67.5	5-8	67.5	5	38	32
Feb 10	1200	bc	12	45	11-16	45	3-5	45	4	38	34
Feb 10	1600	bc	12	45	11-16	45	3-5	45	4	38	34
Feb 10	2000	ovc	12	67.5	7-10	45	3-5	45	3	39	34
Feb 10	2400	ovc	12	67.5	7-10	67.5	1-3	45	2	38	32
Feb 11	0400	sno	10	315	11-16	315	3-5	22.5	2	33	32
Feb 11	0800	sno	2	315	19-25	315	5-8	315	4	34	33
Feb 11	1200	ovc	8	315	22-27	315	5-8	315	5	38	32
Feb 11	1600	ovc	8	315	17-21	315	5-8	315	5	36	35
Feb 11	2000	ovc	8	315	17-21	315	5-8	315	6	37	36
Feb 11	2400	ovc	10	315	11-16	315	5-8	315	5	40	34
Feb 12	0400	ovc	8	var	7-10	315	1-3	315	6	39	36
Feb 12	0800	ovc	6	135	17-21	135	3-5	315	8	38	33
Feb 12	1200	ovc	8	135	17-21	135	5-8	292.5	10	36	32
Feb 12	1600	ovc	8	135	17-21	135	5-8	292.5	8	38	36
Feb 12	2000	ovc	7	135	17-21	135	5-8	135	8	38	37
Feb 12	2400	ovc	8	135	22-27	135	8-12	135	10	38	34
Feb 13	0400	bc	10	112.5	22-27	112.5	8-12	112.5	7	34	30
Feb 15	0800	fair	1	90	11-16	90	<1	90	2	38	38
Feb 15	1200	ovc	5	67.5	11-16	67.5	8-12	90	10	40	40
Feb 15	1600	bc	8	67.5	11-16	67.5	3-5	90	6	42	41
Feb 15	2000	bc	8	67.5	22-27	67.5	5-8	45	8	43	40
Feb 15	2400	bc	8	45	22-27	45	5-8	45	9	44	38

TABLE 46. Primer4 weather and sea state taken from bridge log.

date	local time (hrs)	weather	visibility (miles)	Wind dir. (deg N)	wind speed (knots)	sea direction (deg N)	sea heigth (ft)	swell direction (deg N)	swell height (ft)	Air temp (deg F)	water temp (deg F)
Feb 16	0400	bc	10	67.5	22-27	67.5	8-12	67.5	8	38	36
Feb 16	0800	bc	10	45	11-16	45	3-5	67.5	6	35	30
Feb 16	1200	bc	12	112.5	7-10	45	1-3	90	4	40	36
Feb 16	1600	clr	12	315	4-6	45	1-3	45	4	38	36
Feb 16	2000	clr	12	225	7-10	270	1-3	45	3	34	31
Feb 16	2400	rain	2	90	7-10	270	1-3	0	3	38	36
Feb 17	0400	ovc	6	45	4-6	45	<1	var	0	36	36
Feb 17	0800	ovc	8	45	14-19	45	1-3	45	2	38	37
Feb 17	1200	ovc	8	0	34-40	0	20-40	0	15	35	33
Feb 17	1600	ovc	6	0	17-21	0	8-12	0	10	32	30
Feb 17	2000	bc	10	45	4-6	45	<1	45	6	32	29
Feb 17	2400	bc	12	90	7-10	90	1-3	90	5	34	32
Feb 18	0400	bc	12	135	22-27	135	5-8	135	6	36	34
Feb 18	0800	bc	12	112.5	22-27	112.5	13-20	112.5	10	45	41
Feb 18	1200	clr	12	112.5	22-27	112.5	13-20	112.5	12	42	40
Feb 18	1600	bc	12	112.5	34-40	112.5	13-20	112.5	14	48	44
Feb 18	2000	b	12	157.5	34-40	157.5	13-20	157.5	14	51	45
Feb 18	2400	bc	12	112.5	22-27	112.5	13-20	112.5	15	53	48
Feb 19	0400	bc	10	135	22-27	135	13-20	135	12	50	46
Feb 19	0800	bc	10	112.5	22-27	112.5	8-12	135	12	51	49
Feb 19	1200	ovc	8	135	22-27	135	8-12	135	12	46	40
Feb 19	1600	ovc	8	135	22-27	135	8-12	135	10	48	46
Feb 19	2000	bc	10	157.5	22-27	157.5	13-20	135	12	51	50
Feb 19	2400	ovc	10	112.5	41-47	112.5	13-20	112.5	14	58	55
Feb 20	0400	bc	12	67.5	22-27	90	8-12	112.5	7	49	47
Feb 20	0800	bc	10	45	22-27	45	13-20	45	8	42	39
Feb 20	1200	clr	12	22.5	22-27	45	8-12	45	8	42	40
Feb 20	1600	bc	12	45	4-6	45	1-3	45	4	39	36
Feb 20	2000	bc	12	202.5	11-16	225	3-5	45	3	38	36
Feb 20	2400	clr	12	202.5	17-21	225	3-5	45	4	44	41

TABLE 46. Primer4 weather and sea state taken from bridge log.

date	local time (hrs)	weather	visibility (miles)	Wind dir. (deg N)	wind speed (knots)	sea direction (deg N)	sea heigth (ft)	swell direction (deg N)	swell height (ft)	Air temp (deg F)	water temp (deg F)
Feb 21	0400	ovc	10	135	17-21	135	5-8	135	5	43	42
Feb 21	0800	bc	10	157.5	22-27	157.5	8-12	157.5	5	52	51
Feb 21	1200	ovc	8	157.5	22-27	157.5	8-12	157.5	8	54	54
Feb 21	1600	ovc	6	157.5	22-27	157.5	8-12	157.5	8	52	51
Feb 21	2000	bc	6	157.5	22-27	157.5	8-12	157.5	10	53	53
Feb 21	2400	ovc	6	157.5	22-27	157.5	8-12	157.5	10	50	50
Feb 22	0400	fog	0	135	22-27	135	8-12	135	6	48	48
Feb 22	0800	fog	0	157.5	22-27	157.5	3-5	157.5	3	46	45
Feb 23	1600	bc	12	112.5	22-27	135	8-12	112.5	5	36	34
Feb 23	2000	ovc	12	112.5	22-27	112.5	5-8	112.5	5	38	36
Feb 23	2400	clr	12	90	22-27	90	3-5	90	4	40	40
Feb 24	0400	bc	12	90	11-16	90	3-5	90	4	42	42
Feb 24	0800	bc	10	45	22-27	45	8-12	45	5	44	43
Feb 24	1200	bc	12	67.5	17-21	67.5	5-8	67.5	5	42	40
Feb 24	1600	clr	10	67.5	22-27	67.5	5-8	67.5	6	40	40
Feb 24	2000	bc	12	90	17-21	90	5-8	90	6	44	43
Feb 24	2400	bc	12	90	22-27	90	13-20	90	12	40	40
Feb 25	0400	ovc	10	45	22-27	45	8-12	67.5	8	34	34
Feb 25	0800	clr	10	45	25-31	45	13-20	67.5	12	28	28
Feb 25	1200	clr	10	0	17-21	0	13-20	45	10	36	36
Feb 25	1600	bc	12	0	17-21	0	5-8	45	6	30	30
Feb 25	2000	bc	12	45	11-16	45	3-5	45	6	30	28
Feb 25	2400	bc	12	67.5	11-16	45	3-5	45	5	30	28
Feb 26	0400	bc	12	135	17-21	135	5-8	135	7	39	36
Feb 26	0800	bc	12	135	19-24	135	5-8	135	8	43	41
Feb 26	1200	bc	12	90	22-27	90	5-8	90	9	46	42
Feb 26	1600	bc	10	135	22-27	135	5-8	135	6	43	41
Feb 26	2000	ovc	12	135	17-21	135	5-8	135	6	45	43
Feb 26	2400	rain	4	135	11-16	135	5-8	135	6	46	44

3.2 Summer pickups

Because the weather hindered deck work towards the end of the cruise, only the SE acoustic tomography mooring was recovered during the scheduled part of the Primer4 experiment. The other acoustic sources remained in the water until they could be picked up later. The Central tomography transceiver mooring was recovered in late March, during the MOMAX experiment. The 224 Hz source and the bottom section of the 400 Hz source from the SW site were picked up the following July.

4.0 Acknowledgements

This project was funded by the Office of Naval Research under ONR grant N00014-98-10413 to the Woods Hole Oceanographic Insitution. This support is gratefully acknowledged.

We would like to thank our colleagues, John Kemp, Nick Witzell, John Bouthilette, Mike Caruso, Jim Miller, Ching-Sang Chiu, Chris Miller, Marla Stone, Betsy Doherty, Frank Bahr, Ellen Levy, Paul Fucile, Jerry Dean, and Al Morton who all helped make this experiment a success and this report possible.

We would also like to thank the entire crew of the R/V Endeavor for all their help and support.

And last, but not least, we would like to thank the Capt'n Kidd restaurant for being open during our port calls.

5.0 Appendices

5.1 cruise participants

Leg 1 Feb. 9 -> Feb. 13

Name	Affiliation	Assignment
Glen Gawarkiewicz	WHOI-PO	SeaSoar (Chief Scientist)
Jim Lynch	WHOI-AOPE	Tomography Moorings
John Kemp	WHOI-AOPE	Tomography Moorings
Keith Von der Heydt	WHOI-AOPE	Tomography Moorings
Arthur Newhall	WHOI-AOPE	Tomography Moorings
Warren Witzell	WHOI-AOPE	Tomography Moorings
Brian Sperry	WHOI-AOPE	Tomography Moorings
Scott Worrilow	WHOI-PO	ADCP Moorings
Jim Miller	URI	Tomography Moorings
Gopu Potty	URI	Tomography Moorings
John Bouthillette	WHOI-AOPE	Tomography Moorings
Jan Szelag	URI	CTD, Marine Tech

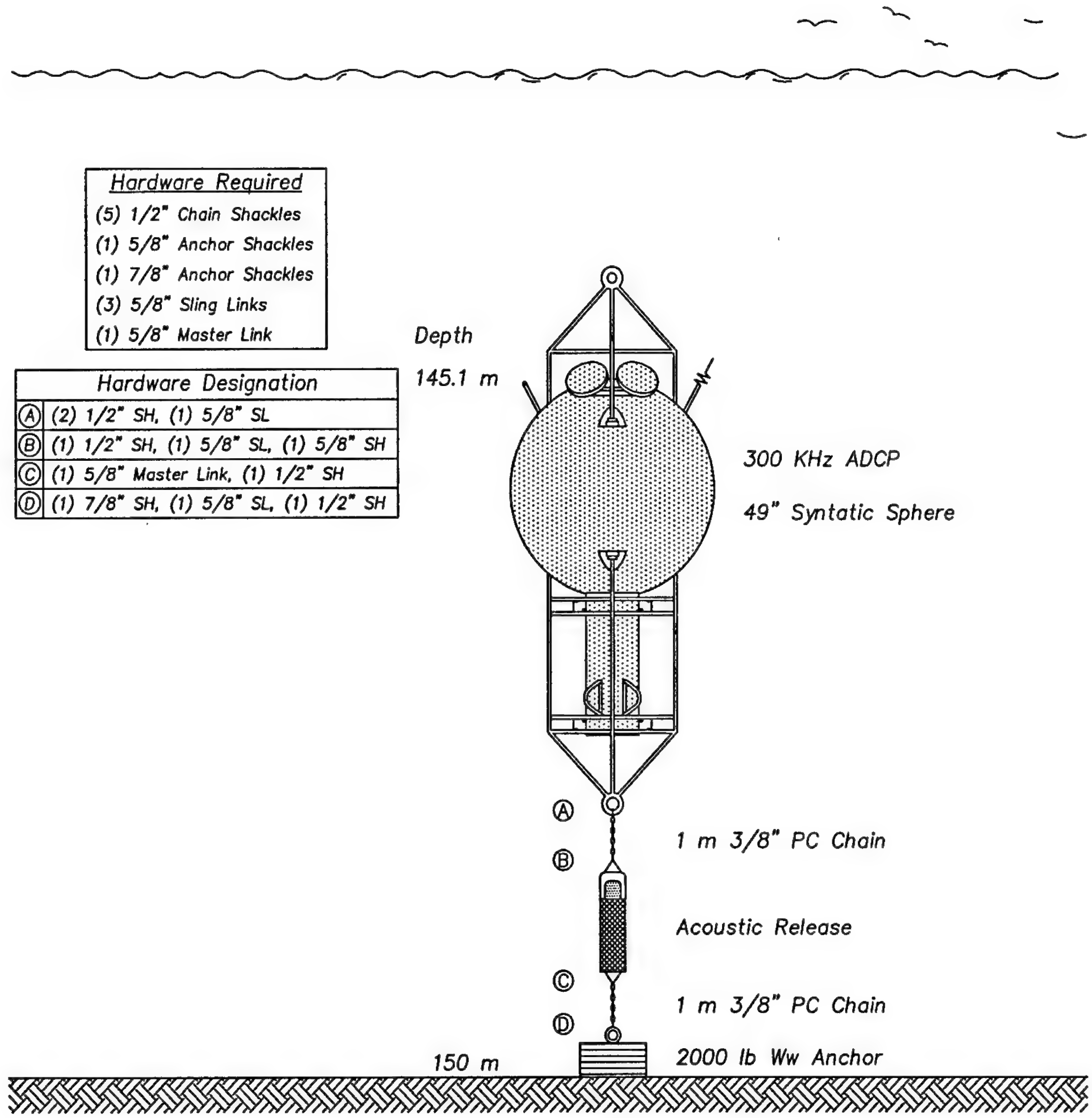
Leg 2 Feb. 15 -> Feb. 21

Name	Affiliation	Assignment
Glen Gawarkiewicz	WHOI-PO	SeaSoar (Chief Scientist)
Frank Bahr	WHOI-PO	SeaSoar
Paul Fucile	WHOI-PO	SeaSoar
Jerry Dean	WHOI-PO	SeaSoar
Al Gordon	WHOI-PO	SeaSoar
Ellen Levy	WHOI-PO	SeaSoar
Wayne Leslie	Harvard	Modelling
Pat Haley	Harvard	Modelling
Jim Lynch	WHOI-AOPE	Tomography Moorings
John Bouthillette	WHOI-AOPE	Tomography Moorings
Arthur Newhall	WHOI-AOPE	Tomography Moorings
Warren Witzell	WHOI-AOPE	Tomography Moorings
Jim Miller	URI	Acoustics - sus
Gopu Potty	URI	Acoustics - sus

Leg 3 Feb. 22 -> Feb 27

Name	Affiliation	Assignment
Glen Gawarkiewicz	WHOI-PO	CTD (Chief Scientist)
Terry McKee	WHOI-PO	CTD
Jennifer Pryztup	Univ. Of S. Carolina	CTD
Jim Lynch	WHOI-AOPE	Tomography Moorings
John Kemp	WHOI-AOPE	Tomography Moorings
John Bouthillette	WHOI-AOPE	Tomography Moorings
Arthur Newhall	WHOI-AOPE	Tomography Moorings
Warren Witzell	WHOI-AOPE	Tomography Moorings
Jim Millller	URI	Tomography Moorings
Gopu Potty	URI	Tomography Moorings
Ching-Sang Chiu	NPS	Tomography Moorings
Marla Stone	NPS	Tomography Moorings
John Colosi	WHOI-AOPE	CTD
Jan Szelag	URI	CTD
Martin Visbek	LDEO	CTD
Manfred Mensch	LDEO	Tracers

5.2 Predeployment mooring drawings



Hardware Required
(5) 1/2" Chain Shackles
(1) 5/8" Anchor Shackles
(1) 7/8" Anchor Shackles
(3) 5/8" Sling Links
(1) 5/8" Master Link

	Hardware Designation
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
C	(1) 5/8" Master Link, (1) 1/2" SH
D	(1) 7/8" SH, (1) 5/8" SL, (1) 1/2" SH

Winter Primer Experiment, 300 KHz ADCP Mooring

"P"

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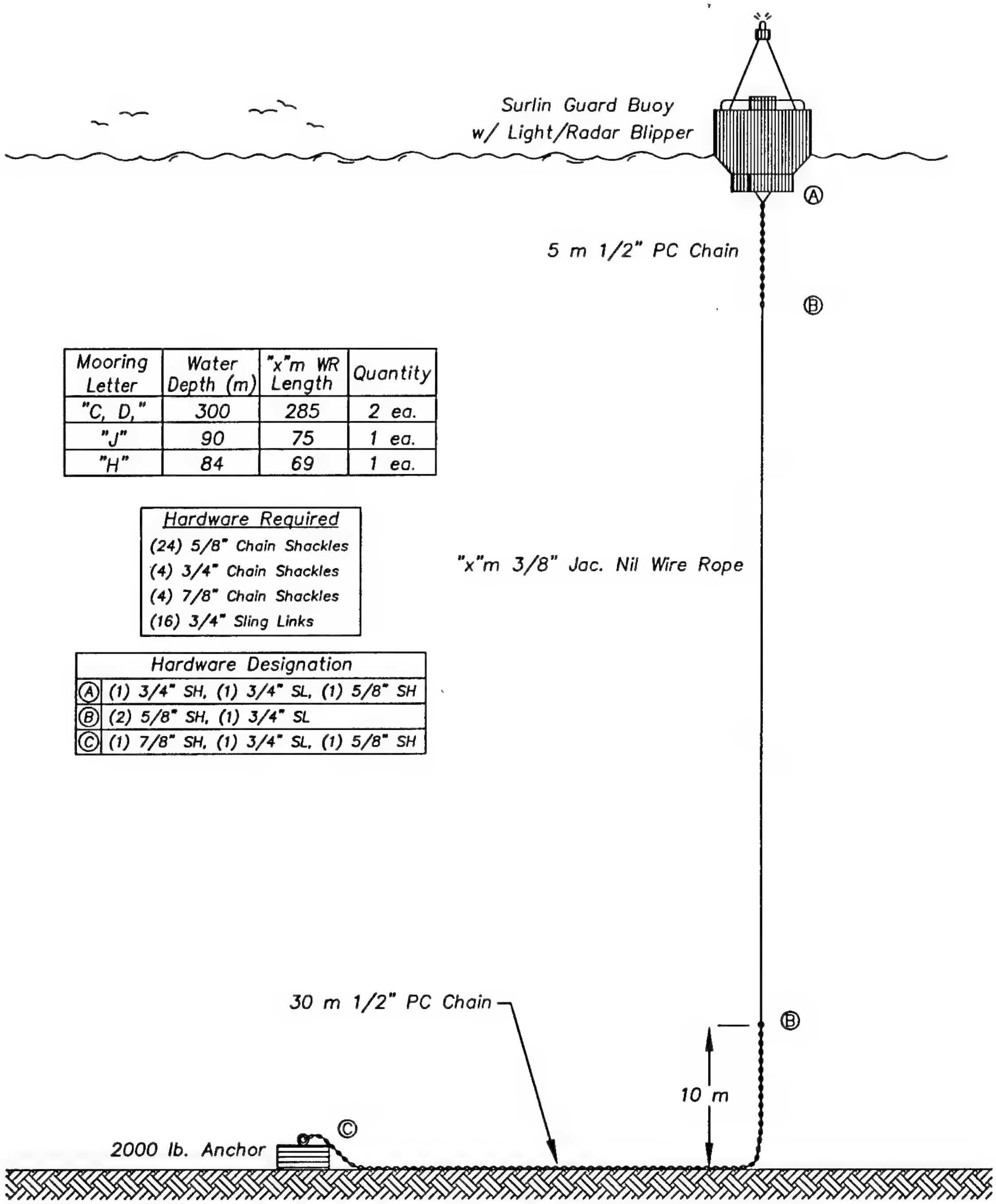

Mooring Letter	Water Depth (m)	"x"m WR Length	Quantity
"C, D,"	300	285	2 ea.
"J"	90	75	1 ea.
"H"	84	69	1 ea.

Hardware Required
(24) 5/8" Chain Shackles
(4) 3/4" Chain Shackles
(4) 7/8" Chain Shackles
(16) 3/4" Sling Links

Hardware Designation	
Ⓐ	(1) 3/4" SH, (1) 3/4" SL, (1) 5/8" SH
Ⓑ	(2) 5/8" SH, (1) 3/4" SL
Ⓒ	(1) 7/8" SH, (1) 3/4" SL, (1) 5/8" SH

Winter Primer Experiment, Guard Buoy Moorings (4 Required)

"C, D, H, J"

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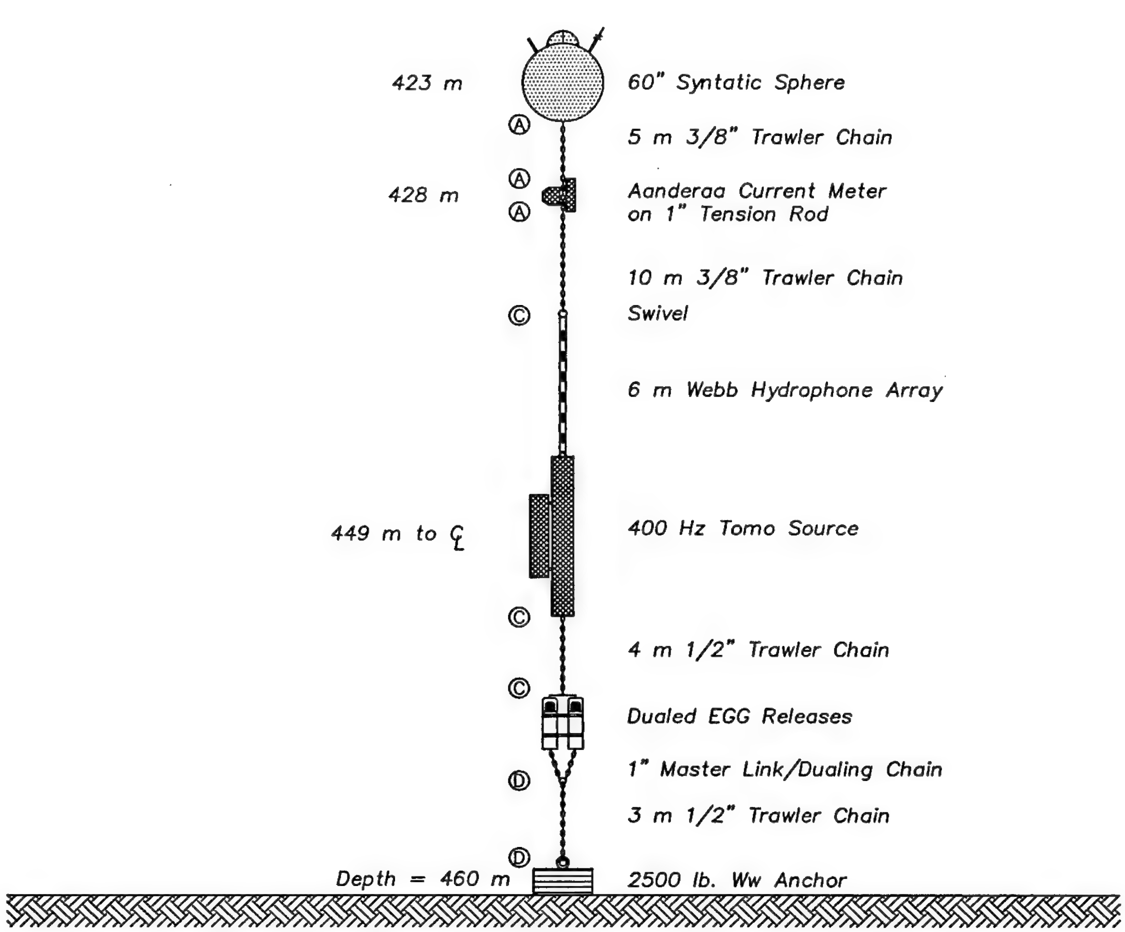
Hardware Required
(11) 1/2" Chain Shackles
(3) 5/8" Anchor Shackles
(1) 3/4" Anchor Shackles
(2) 7/8" Anchor Shackles
(8) 5/8" Sling Links
(1) 1" Master Link

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1" Master Link, (1) 3/4" SH, (1) 1/2" SH
C	(1) 1/2" SH, (2) 5/8" SL, (3) 5/8" SH
D	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH



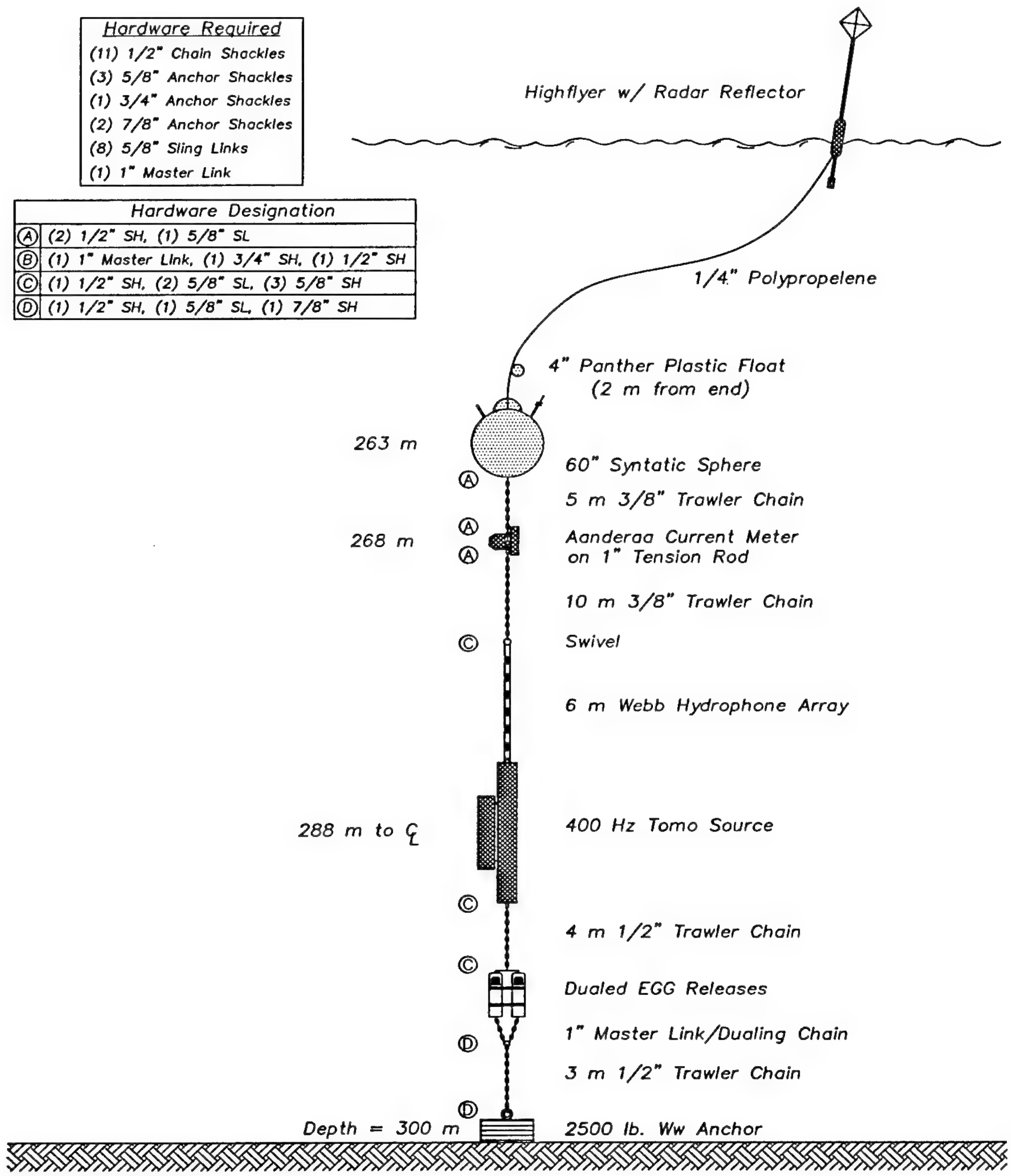
Winter Primer Experiment, 400Hz Tomo Source Mooring, Central

Betsey Doherty date: 07/09/96
file: WNTRPRMR rev: 01/15/97
John Kemp Sheet 3 of 12

"F"

Hardware Required
(11) 1/2" Chain Shackles
(3) 5/8" Anchor Shackles
(1) 3/4" Anchor Shackles
(2) 7/8" Anchor Shackles
(8) 5/8" Sling Links
(1) 1" Master Link

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1" Master Link, (1) 3/4" SH, (1) 1/2" SH
C	(1) 1/2" SH, (2) 5/8" SL, (3) 5/8" SH
D	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH



Winter Primer Experiment, 400Hz Tomo Source Mooring, SE

"E"

Betsey Doherty	date: 07/09/96
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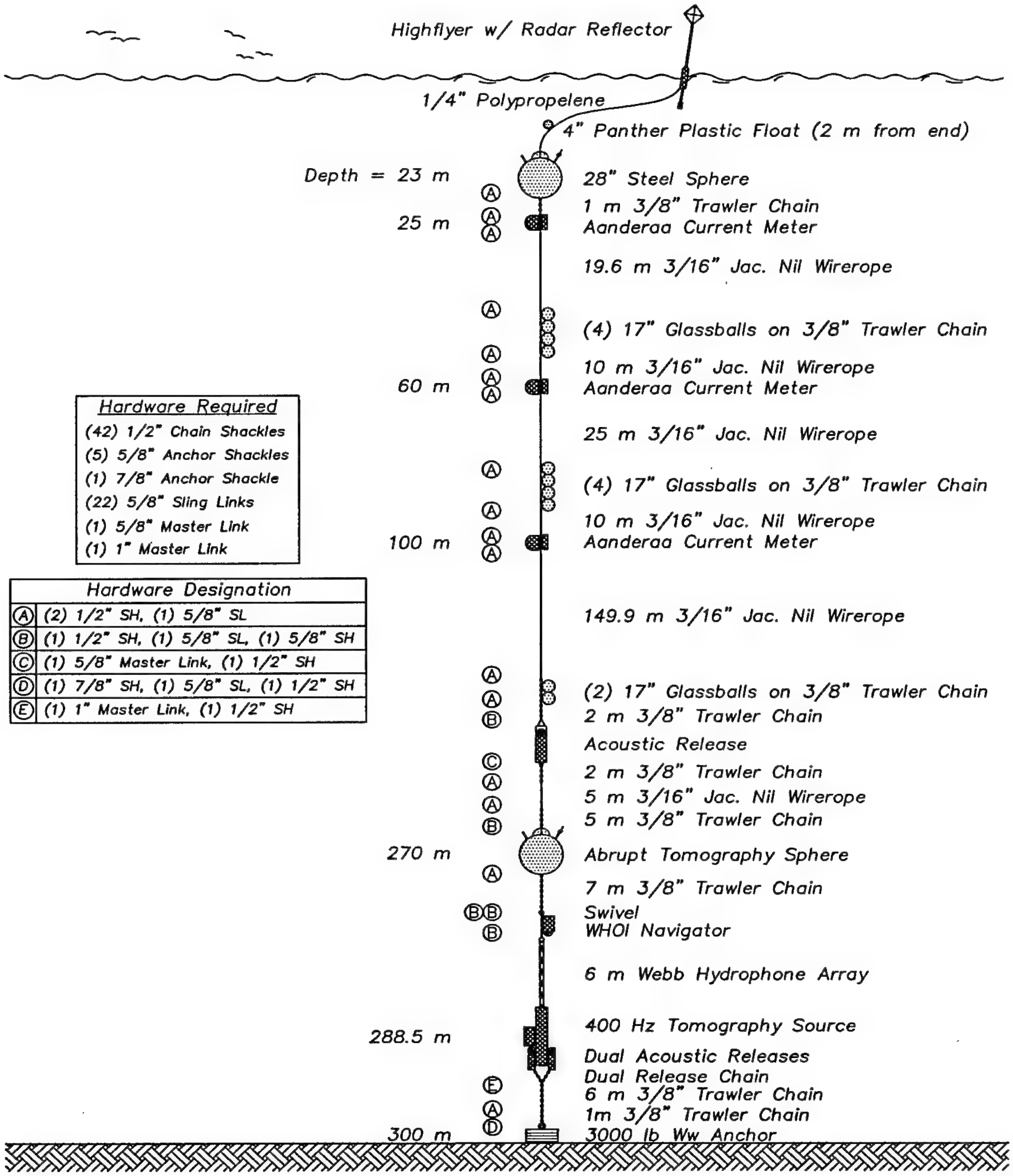

Hardware Required
(42) 1/2" Chain Shackles
(5) 5/8" Anchor Shackles
(1) 7/8" Anchor Shackle
(22) 5/8" Sling Links
(1) 5/8" Master Link
(1) 1" Master Link

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
C	(1) 5/8" Master Link, (1) 1/2" SH
D	(1) 7/8" SH, (1) 5/8" SL, (1) 1/2" SH
E	(1) 1" Master Link, (1) 1/2" SH

Winter Primer Experiment, Thermistor Mooring, 400 Hz Tomography Source, SW

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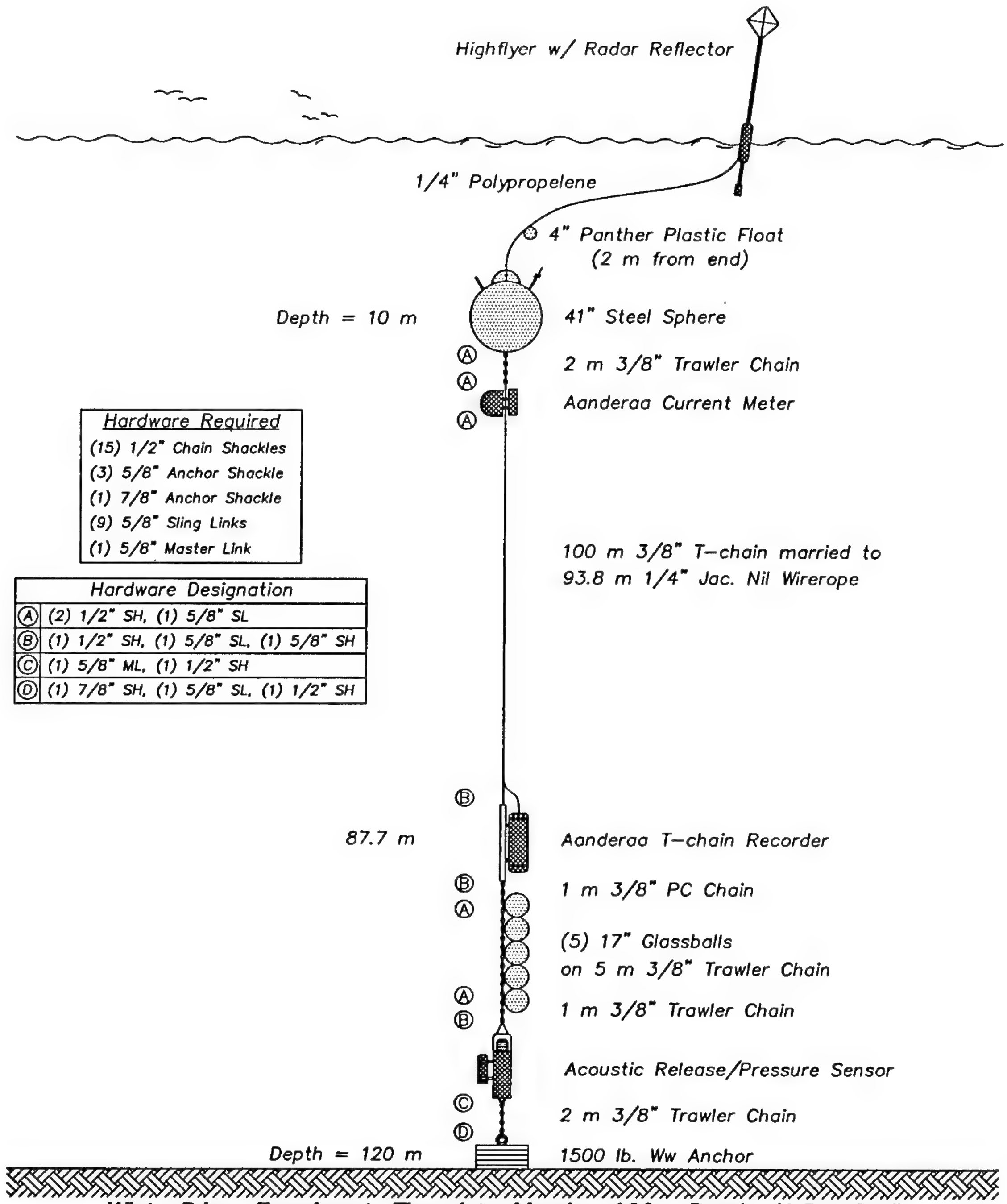
John Kemp Sheet 5 of 12	

"B"



Hardware Required
(15) 1/2" Chain Shackles
(3) 5/8" Anchor Shackle
(1) 7/8" Anchor Shackle
(9) 5/8" Sling Links
(1) 5/8" Master Link

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
C	(1) 5/8" ML, (1) 1/2" SH
D	(1) 7/8" SH, (1) 5/8" SL, (1) 1/2" SH

Winter Primer Experiment, Thermistor Mooring, 120 m Depth, (1 Required)

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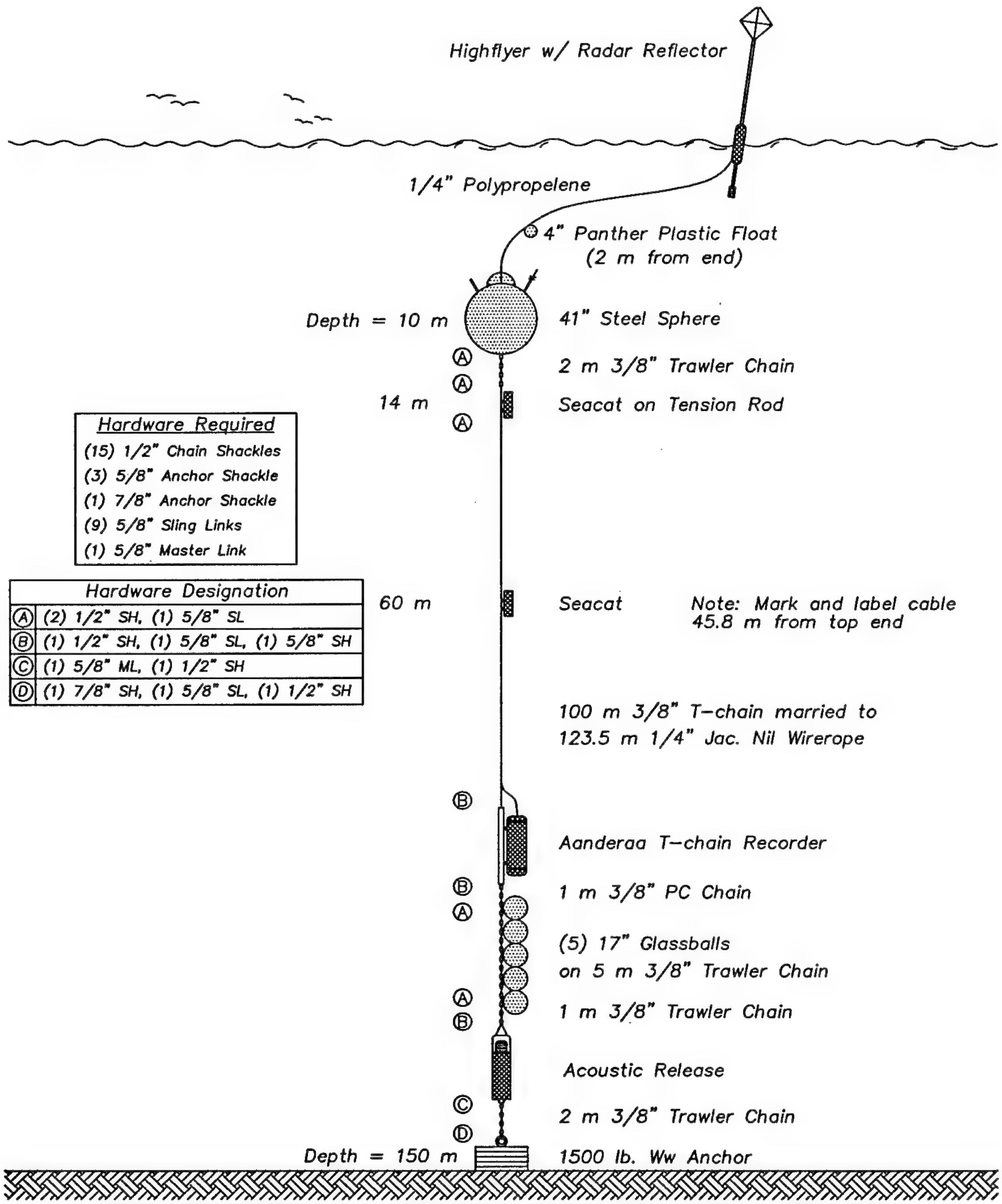
"N"



Winter Primer Experiment, Thermistor Mooring, 150 m Depth, (1 Required)

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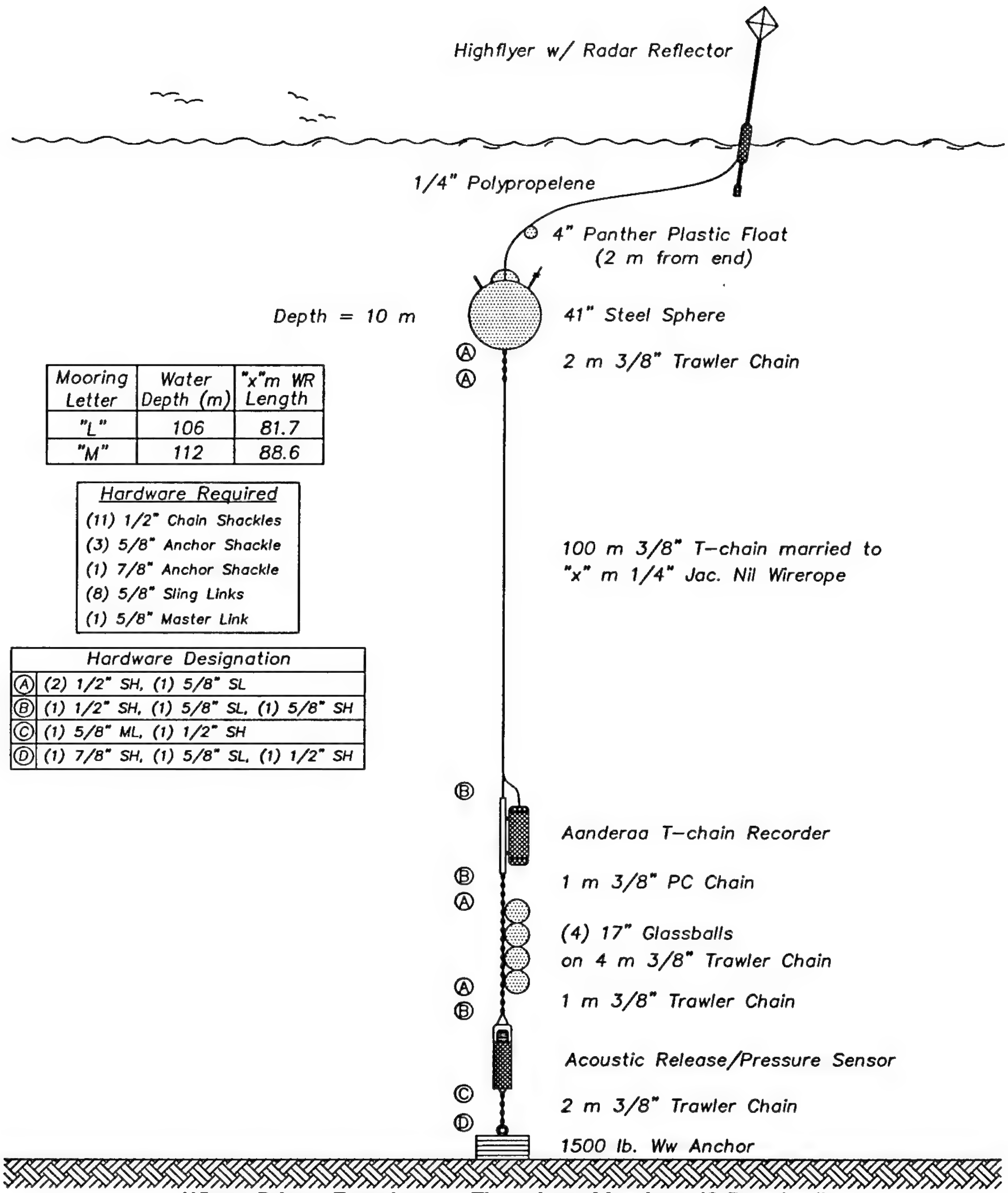
"O"



Mooring Letter	Water Depth (m)	"x"m WR Length
"L"	106	81.7
"M"	112	88.6

Hardware Required
(11) 1/2" Chain Shackles
(3) 5/8" Anchor Shackle
(1) 7/8" Anchor Shackle
(8) 5/8" Sling Links
(1) 5/8" Master Link

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
C	(1) 5/8" ML, (1) 1/2" SH
D	(1) 7/8" SH, (1) 5/8" SL, (1) 1/2" SH

Winter Primer Experiment, Thermistor Mooring, (2 Required)

"L, M"

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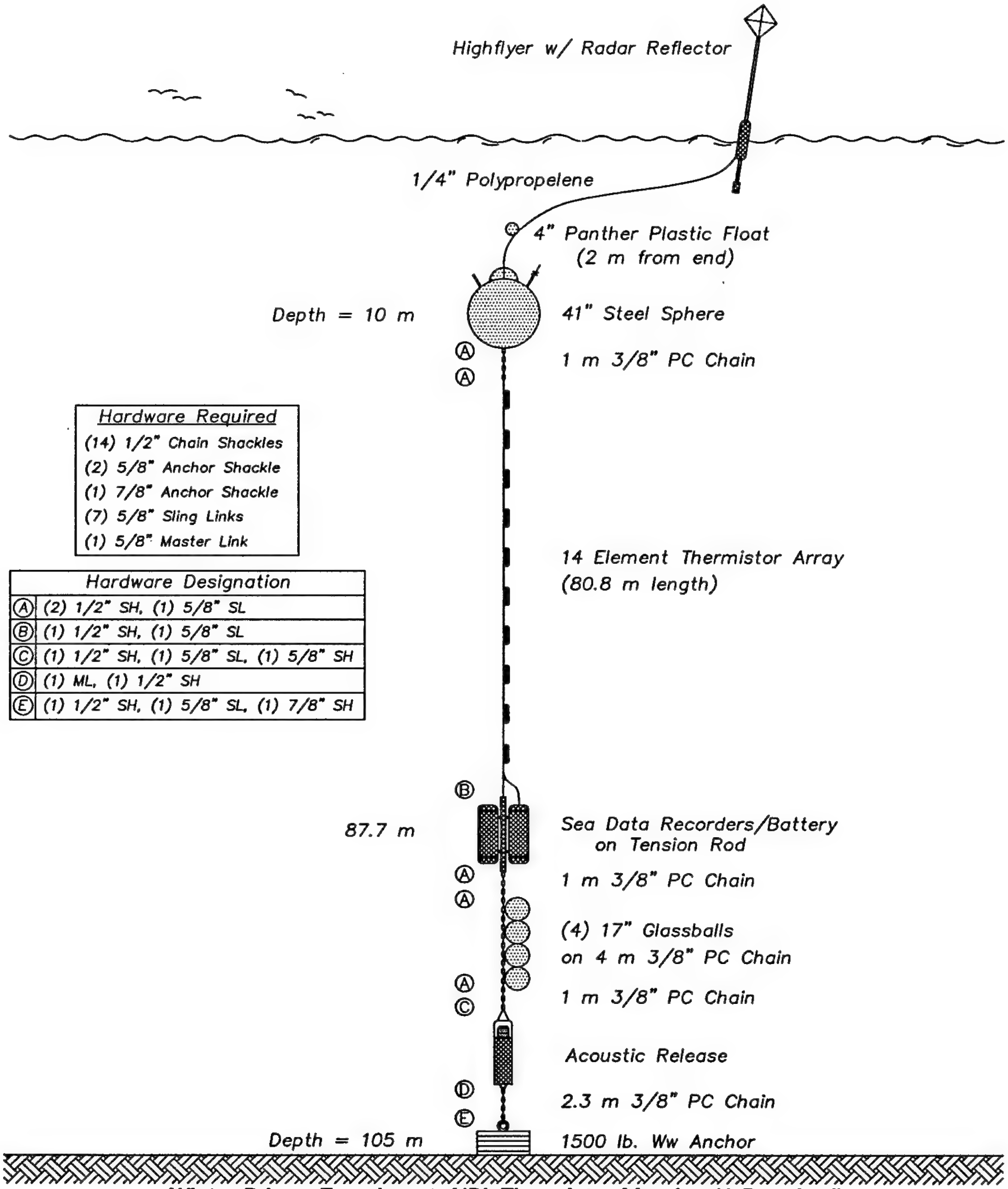

Hardware Required
(14) 1/2" Chain Shackles
(2) 5/8" Anchor Shackle
(1) 7/8" Anchor Shackle
(7) 5/8" Sling Links
(1) 5/8" Master Link

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL
C	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
D	(1) ML, (1) 1/2" SH
E	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH

Winter Primer Experiment, NRL Thermistor Mooring (1 Required)

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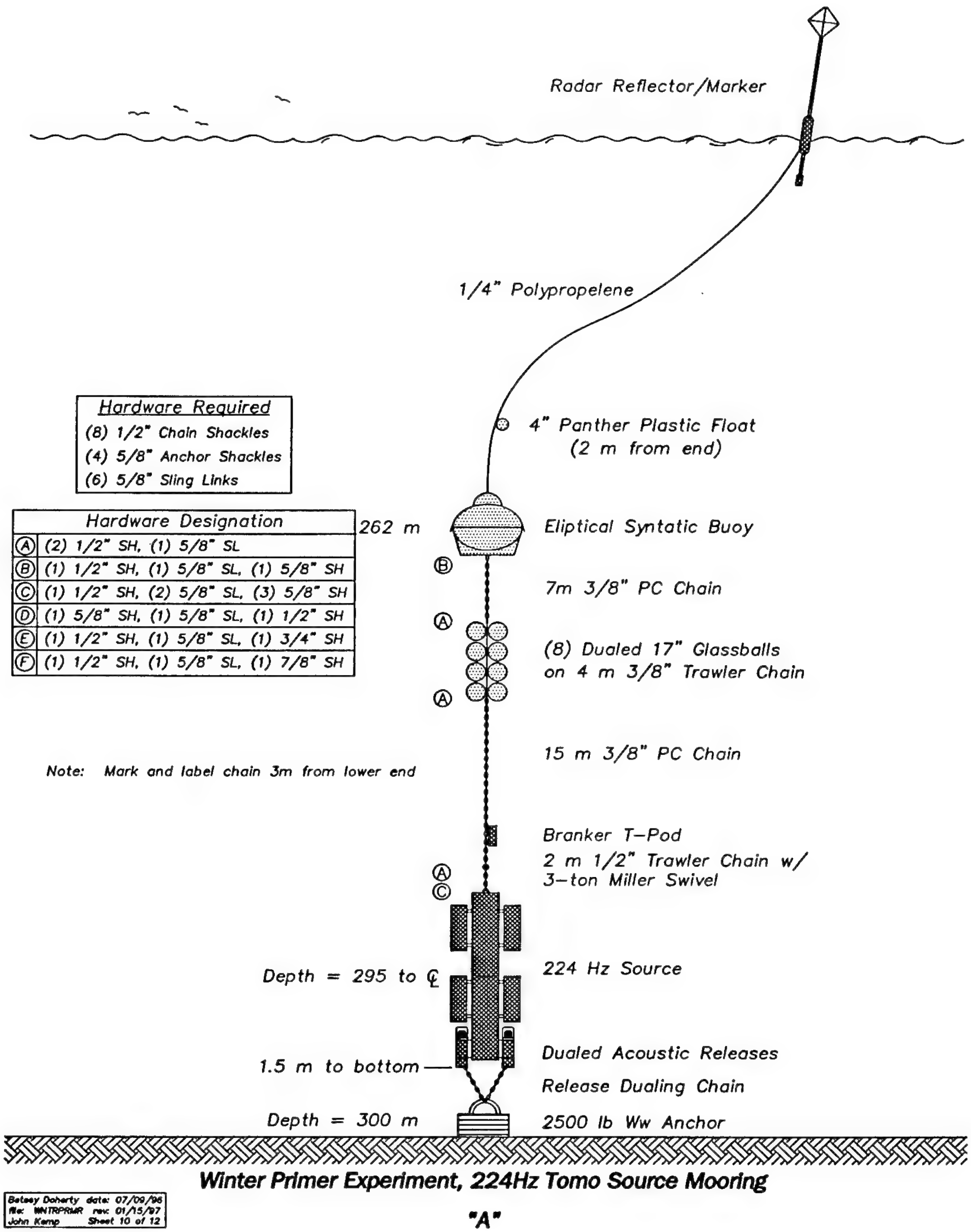
"K"

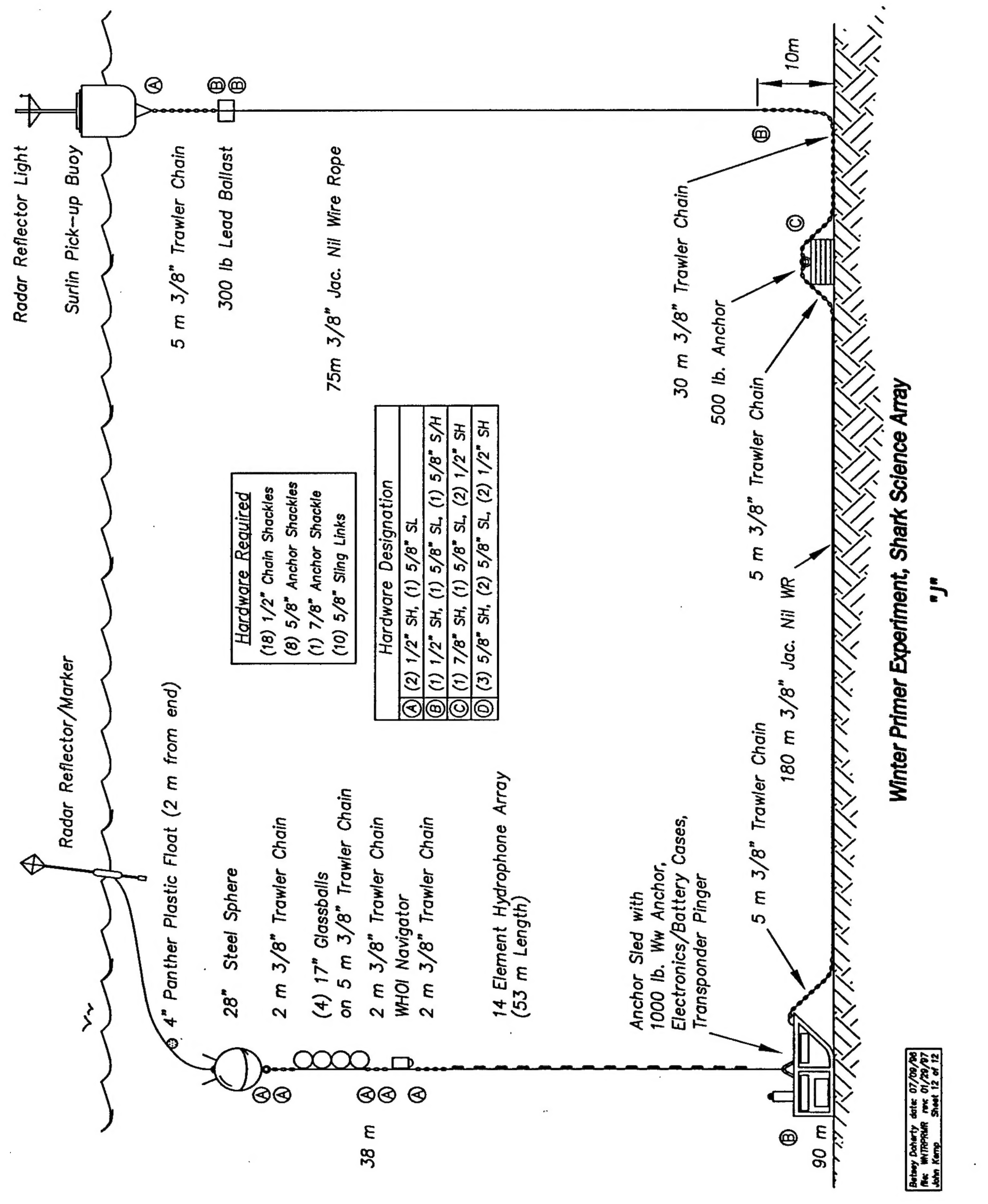


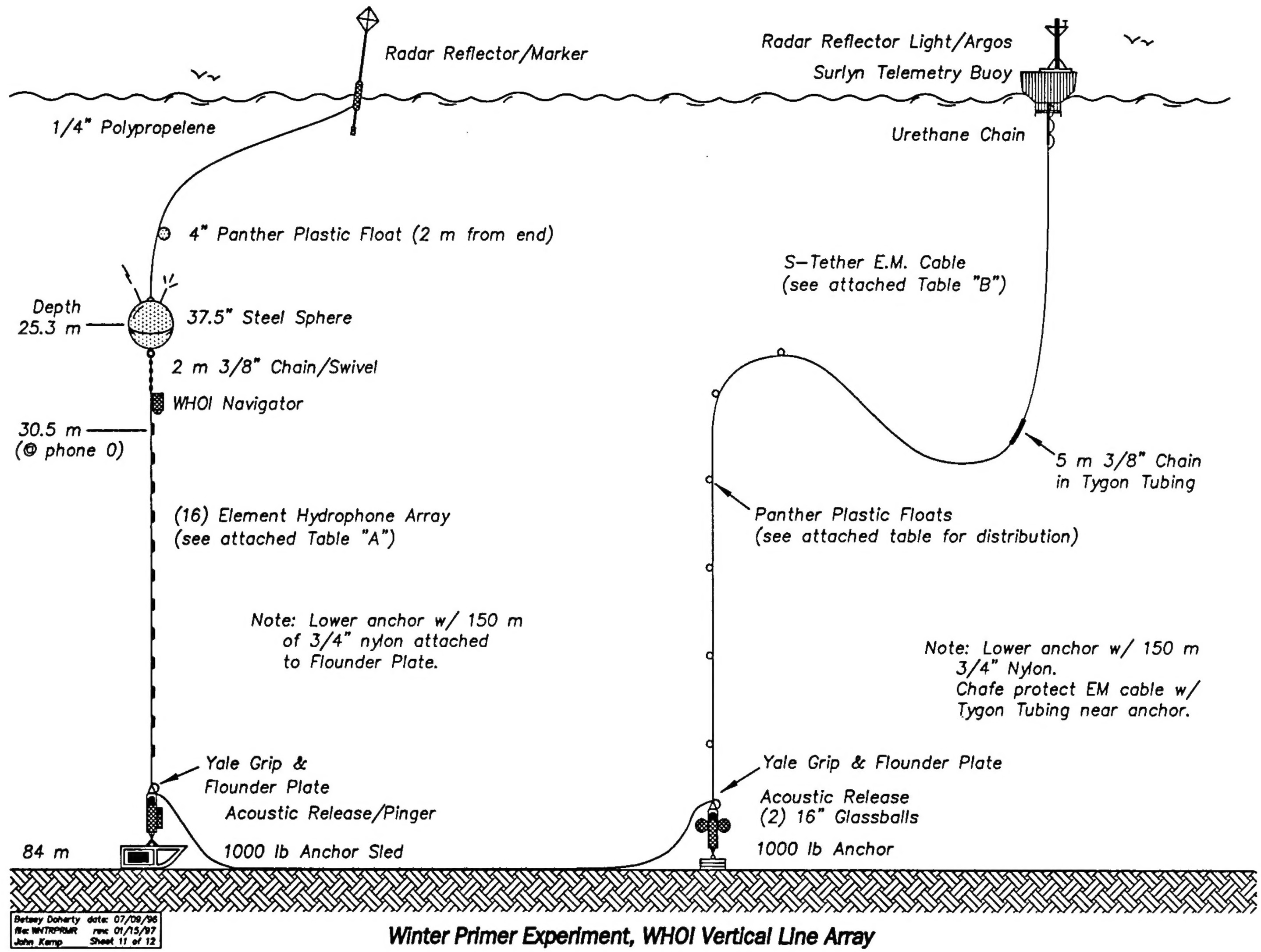
Hardware Required
(8) 1/2" Chain Shackles
(4) 5/8" Anchor Shackles
(6) 5/8" Sling Links

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
C	(1) 1/2" SH, (2) 5/8" SL, (3) 5/8" SH
D	(1) 5/8" SH, (1) 5/8" SL, (1) 1/2" SH
E	(1) 1/2" SH, (1) 5/8" SL, (1) 3/4" SH
F	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH

Winter Primer Experiment, 224Hz Tomo Source Mooring

"A"


Radar Reflector/Marker
4" Panther Plastic Float (2 m from end)
28" Steel Sphere
2 m 3/8" Trawler Chain
(4) 17" Glassballs
on 5 m 3/8" Trawler Chain
2 m 3/8" Trawler Chain
WHOI Navigator
2 m 3/8" Trawler Chain
14 Element Hydrophone Array
(53 m Length)
38 m
90 m
Anchor Sled with
1000 lb. Ww Anchor,
Electronics/Battery Cases,
Transponder Pinger
5 m 3/8" Trawler Chain
180 m 3/8" Jac. Nil WR
5 m 3/8" Trawler Chain
500 lb. Anchor
30 m 3/8" Trawler Chain
10m
Radar Reflector Light
Surlin Pick-up Buoy
5 m 3/8" Trawler Chain
300 lb Lead Ballast
75m 3/8" Jac. Nil Wire Rope
Hardware Required
(18) 1/2" Chain Shackles
(8) 5/8" Anchor Shackles
(1) 7/8" Anchor Shackle
(10) 5/8" Sling Links
Hardware Designation
A (2) 1/2" SH, (1) 5/8" SL
B (1) 1/2" SH, (1) 5/8" SL, (1) 5/8" S/H
C (1) 7/8" SH, (1) 5/8" SL, (2) 1/2" SH
D (3) 5/8" SH, (2) 5/8" SL, (2) 1/2" SH
Winter Primer Experiment, Shark Science Array
"J"
Betsey Doherty date: 07/09/96
file: WNTRPRMR rev: 01/29/97
John Kemp Sheet 12 of 12



Winter Primer Experiment, WHOI Vertical Line Array

"G"

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REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-98-19	2.	3. Recipient's Accession No.

4. Title and Subtitle Preliminary Acoustic and Oceanographic Observations from the Winter Primer Experiment	5. Report Date October 1998
	6.
7. Author(s) Arthur Newhall Keith Von der Heydt	8. Performing Organization Rept. No. WHOI-98-19
9. Performing Organization Name and Address Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543	10. Project/Task/Work Unit No.
	11. Contract(C) or Grant(G) No. (C) N00014-98-10413 (G)
12. Sponsoring Organization Name and Address Office of Naval Research	13. Type of Report & Period Covered Technical Report
	14.

15. Supplementary Notes

This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-98-19.

16. Abstract (Limit: 200 words)

A joint acoustics and physical oceanography experiment was conducted in the winter of 1997 on the shellbreak and continental slope south of New England in the Middle Atlantic Bight (figure 1). This experiment, Primer4, provided a seasonal contrast to the previous summer Primer3 experiment and had the same goals and tasks: to study the thermohaline variability and structure of the shelfbreak front and its effects on acoustic propagation. To accomplish the linked oceanographic and acoustic objectives of this experiment, a combination of measurements (fig 2) were made. Seasoar hydrography, shipboard ADCP measurements, Satellite IR sea surface temperature field observations, and AXBT drops were employed to study the larger scale oceanographic fields. To study the finer scale, which includes internal waves, a number of rapid-sampling thermistor strings and current meters, including a moored, upward looking ADCP, were deployed. The acoustics components consisted of three 400 Hz tomography transceivers, a 224 Hz source and two hydrophone arrays. To study the geoacoustic parameters in the bottom a number of SUS charges were also deployed. The field setup was approximately the same for both the summer 1996 and winter 1997 experiments; however the weather conditions and the thermal structure of the mixed layer were radically different. This report is dedicated to the data from the Winter 1997 Primer4 experiment.

17. Document Analysis a. Descriptors

Primer Experiment
Shallow Water Acoustics
Shelfbreak Front

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Approved for public release; distribution unlimited.	UNCLASSIFIED	125
	20. Security Class (This Page)	22. Price

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